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POLLUTION OF INTERSTATE WATERS OF THE LOWER COLUMBIA RIVER BONNEVILLE DAM TO CATHLAMET, WASHINGTON

Public Health Service
Portland, Oregon

August 1965

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A REPORT

POLLUTION OF INTERSTATE WATERS OF THE

LOWER COLUMBIA RIVER

BONNEVILLE DAM TO CATHLAMET, WASHINGTON

August 1965

DIVISION OF WATER SUPPLY & POLLUTION CONTROL
U. S. PUBLIC HEALTH SERVICE
PORTLAND, OREGON

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A Report

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U. S. Department of Health, Education, and Welfare
Public Health Service
Water Supply and Pollution Control Program, Pacific Northwest
Region IX, Portland, Oregon

August 1965

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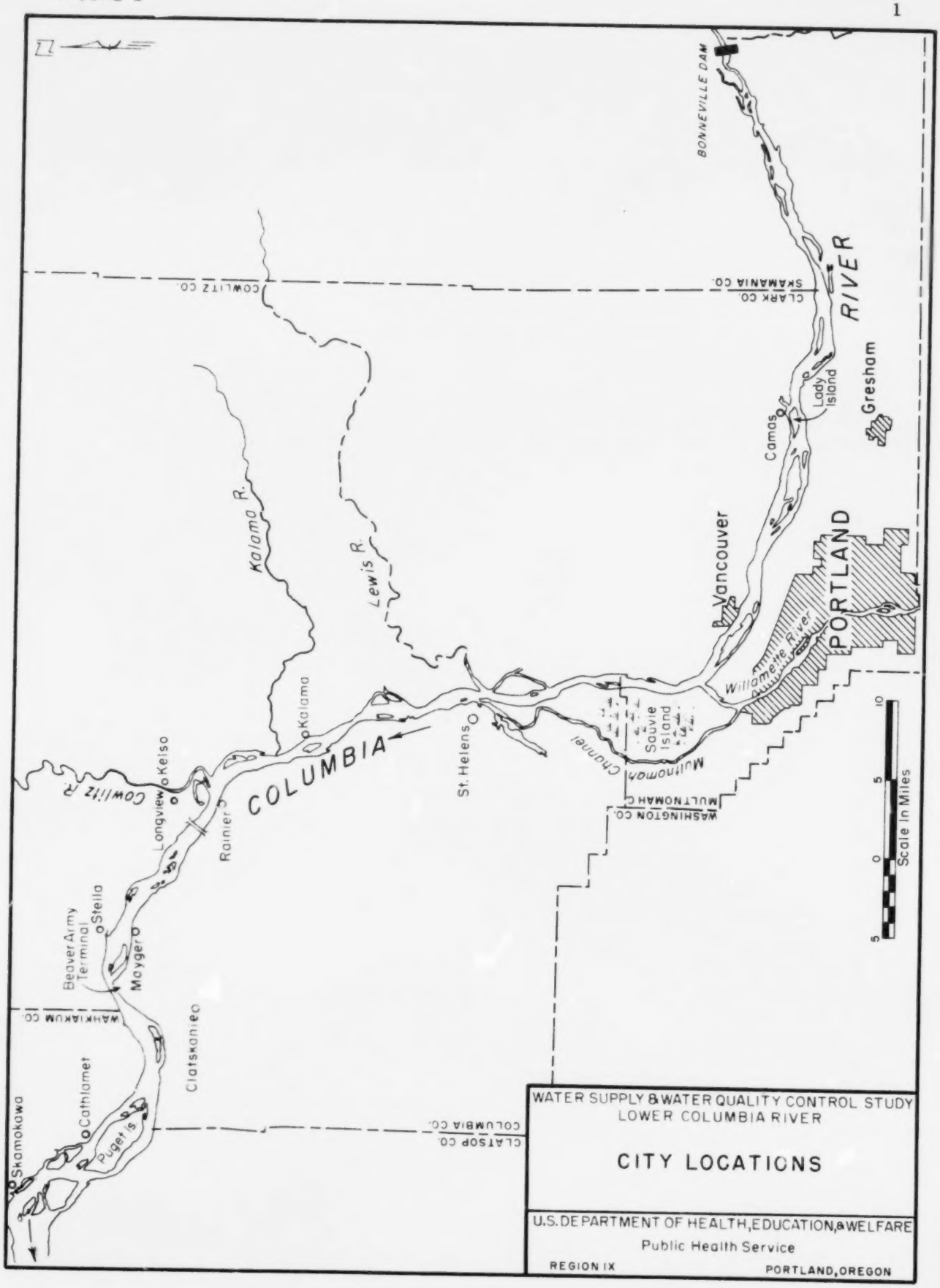

WATER SUPPLY & WATER QUALITY CONTROL STUDY
LOWER COLUMBIA RIVER

CITY LOCATIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX PORTLAND, OREGON

SUMMARY AND CONCLUSIONS

SUMMARY

The section of the Lower Columbia River from Bonneville Dam to Cathlamet, Washington, with which this report is concerned, is shown in Figure I. This 104-mile reach is more highly developed than any other comparable length of the main river.

For more than 25 years the quality of the waters of the Lower Columbia River has been adversely affected by abundant slime growths which flourish periodically. Materials contained in wastes discharged along the 80-mile stretch of the river between Camas and Cathlamet supply the nutrients for the slime growths. Commercial fishermen's nets become coated with slime, and they must frequently cease fishing or be highly selective in placing their nets to prevent having them swamped with slime. Fishermen report that fibers in the slime become entangled in the knots of their nets, making slime removal an extremely difficult operation. Sport fishing and other forms of water-contact recreation have also been adversely affected by the slime growths.

In 1958 a conference was held under the provisions of the Federal Water Pollution Control Act. The conference was reconvened in 1959 to review progress made during the previous year and to adopt an action program for the abatement of pollution.

Wastes are discharged directly to the Columbia River from ten cities and towns, including the City of Portland; three grain washing plants; two food-processing plants; a malting plant; a brewery; and seven pulp and

paper mills. The concentrated sulfite waste liquor from one of these seven mills is barged for discharge to the Columbia River during critical oxygen and low-flow conditions in the Willamette River. These sources represent an average daily waste discharge of about 865,000 pounds of Biochemical Oxygen Demand (BOD) and 300,000 pounds of Volatile Suspended Matter (VSM). Of these, approximately 780,000 pounds of BOD and 250,000 pounds of VSM are derived from pulp and paper mill operations.

All of the cities and towns provide primary treatment with effluent disinfection for the wastes discharged directly to the Columbia River. Within the City of Portland there remain 27 city-owned and 25 private sewers which discharge untreated wastes to the Willamette River. Based on limited information, the wastes discharged to the Willamette River appear to have very little effect on the Columbia River. The longer flow period in the lower portion of the Willamette allows time for the stabilization of most of the wastes before they reach the Columbia. The effect of these wastes would be increased when flood conditions exist only on the Willamette River.

All of the industries that discharge wastes to the Columbia River, except the pulp and paper mills, provide treatment which complies with the action program adopted by conferees in 1959. While the pulp and paper mills have made some operational changes to reduce the pollution load, the 1,022 tons/day increase in pulp production and 627 tons/day increase in paper production since 1959 have resulted in an average daily net increase of approximately 165,000 pounds of BOD and 55,000 pounds of VSM in their waste discharge. Of the 4,798 tons/day of pulp production from the seven

mills, 742 tons are produced by the sulfite process with no recovery of the base cooking chemicals. Approximately one-half of the average daily BOD loading to the river from the mills is contained in spent sulfite liquor from the 742 tons of pulp produced by the sulfite process. One of the sulfite mills constructed a holding lagoon in which most of its wastes are held for six days, with discharge on the seventh day. This facility did reduce slime growths for a distance below the mill, but greatly complicated the slime problem further downstream. All seven mills use savealls with the paper machines.

Previous and current investigations have revealed that the wastes from the seven pulp and paper mills are the principal source of the nutrient material required for slime growth. While previous investigators believed the slime grew on fixed surfaces and broke loose to foul fishermen's nets, the review of German literature, substantiated by investigations on the Columbia River, has shown that the fibers in these wastes serve as a substrate for the growth of slime. Furthermore, the presence of fiber in the Columbia River severely complicates the problem of slime removal from nets. Laboratory studies have indicated that slime will grow when the spent sulfite solids concentration is as low as 20 to 50 parts per million (ppm) (based on 10 per cent solids), but the growth is lessened at the lower concentrations. However, stream studies have shown excellent growth at concentrations as low as 10 to 20 ppm (10 per cent solids basis). Also, one of the previous investigators reported that the optimum temperature range for slime growth was 10^{o} C. to 15^{o} C.

Late in 1960, a reporting program was initiated in cooperation with commercial fishermen to gather more information on the frequency of

occurrence and severity of the slime problem. Reports of slime occurrence at drifts were received during a discharge range of 81,600 cubic feet per second (cfs) to 437,130 cfs and a temperature range of 5.6° C. to 21.1° C. The most severe condition occurred when river discharge ranged from 184,200 to 235,390 cfs and temperature ranged from 10° C. to 12° C. These reports indicate the severity of slimes frequently increased during the passage of the intermittent waste discharge from the Crown Zellerbach pulp mill's waste-holding lagoon.

A waste control and treatment program for pulp and paper wastes discharged to the Columbia River is reasonable and attainable. Primary treatment to remove 70 per cent of the VSM will greatly reduce the amount of objectionable fiber in the river. The barging of spent sulfite liquor to the Columbia River shou'd be discontinued. Mills at Camas and Vancouver should provide the necessary means to obtain a 70 per cent reduction in the BOD loading presently discharged in spent sulfite liquor.

Table I shows the total VSM and BOD loadings presently discharged to the river by each of the seven mills. These reported values were furnished by the mills to the respective State pollution control agencies. Table I also shows the calculated loadings that would remain following the installation of primary treatment at all of the mills and the remaining BOD loading after the 70 per cent reduction in loadings from spent sulfite liquor. The residual BOD loading can be further reduced by biological treatment, or other disposal means should this prove necessary.

CONCLUSIONS

The following conclusions are based on observations and recorded river conditions:

TABLE I

COLUMBIA RIVER - CAMAS TO LONGVIEW, WASHINGTON
PULP AND PAPER INDUSTRY
UNTREATED AND RECOMMENDED WASTE LOADINGS

	Pounds Volatile Suspended Matter/Day [1]		Pounds 5 day BOD/Day		
	Reported Discharge	With Primary Treatment	Reported Discharge	With 70% SWL-BOD Removed	With 15% Reduction by Primary Treatment
Crown Zellerbach Camas, Wash.	81,700	24,500	325,000	170,000 [2]	144,500
Boise Cascade Vancouver, Wash.	16,200	4,900	133,000	48,000 [2]	40,800
Publishers Paper Oregon City, Oregon	No Report	- -	60,000	Barging to be discontinued	
Kaiser Gypsum St. Helens, Oregon	8,575 7,700 [3]	2,300	7,025	7,025	5,970
Boise Cascade St. Helens, Oregon	40,100 36,100 [3]	10,800	23,250	23,250	19,760
Longview Fiber Longview, Wash.	47,500	14,300	80,000	80,000	68,000
Weyerhaeuser Co. Longview, Wash.	59,000	17,700	150,000	150,000	127,500
Totals- - - - - - - - -	248,100	74,500	778,275	478,275	406,530
% Reduction - - - - - - -		70%		39%	48%
Population Equivalent [4]			4,578,000	2,813,000	2,391,000

1/ VSM as determined by American Public Health Association (APHA) standard methods.
2/ Adjusted on calculated total B.O.D. produced.
3/ Volatile suspended matter assumed 90% of total suspended matter.
4/ Based on 0.17 lbs. BOD/capita/day.

1. Slime interferes with commercial and sport fishing by fouling nets and gear.

2. The wastes from the pulp and paper industry are primarily responsible for this problem. The additional wastes resulting from increased production since 1959 have compounded the problem.

3. Wood fibers add strength and body to the slimes and make them more difficult to remove from nets and sport fishing gear. These fibers are discharged along with the dissolved organic wastes from the pulp and paper mills from Camas to Longview. There is no fiber problem above Camas. Fiber decomposition is so slow that with existing river flows the increment of fibers from each successive waste discharge increases the downstream concentration.

4. The action program for the Lower Columbia River Conference adopted September 3, 1959, called for a minimum of primary sedimentation or its equivalent for all wastes discharged to the river. The 248,000 pounds/day of VSM presently discharged to the river are essentially all wood fibers which are not being satisfactorily assimilated, and primary treatment for the removal of these fibers is needed now.

5. Pulp production has increased from 3,776 tons/day to 4,798 tons/day since 1959. As a result, the average loading to the river has increased from 613,000 to 778,000 pounds BOD/day.* The daily organic load imposed by this industry is nearly six times as great as that from all other sources combined, and this is increased to more than 28 times during the once-a-week discharge from the one holding pond.

*That portion of the BOD increase for the three Oregon mills has been calculated to be proportional to the increase in their pulp production.

6. Nearly half of the average daily BOD loading is contributed by three mills using the sulfite process with no recovery of the base cooking chemicals.

7. A slime concentration that severely interferes with commercial and sport fishing develops when the river flow is less than 220,000 cfs (at Mayger) and the water temperature is 10^{o} to 15^{o} C.

8. Slimes which interfere with fishing between Camas and Vancouver occur only during the passage of the once-a-week waste discharge from Lady Island. With critical flow and temperature conditions, the stored load of 1,960,000 pounds of BOD discharged in a 24-hour period compounds the slime problem downstream, particularly in the Mayger area. The intermittent waste discharge program has not proved successful.

9. The major part of the slime develops on, and becomes entangled with, wood fibers and other debris in the river rather than on the streambed as was previously believed. The results of the 1964 sampling program show that slime does grow on suspended debris, as reported in the German literature.

10. Most of the objectionable wood fibers contained in mill wastes can be removed by primary treatment. The total organic loading to the river, as measured by BOD, can be decreased about 40 per cent by reduction in waste loadings from spent sulfite liquor discharged to the river at the Camas and Vancouver mills and the total elimination of barged spent sulfite liquor discharged to the Columbia River.

11. Sufficient progress has not been made by the pulp and paper industry to comply with the pollution abatement program adopted by the 1959 conference.

****

Sewage and industrial wastes discharged to the Lower Columbia River cause pollution in the interstate waters of the Columbia River which endangers the health or welfare of persons in Oregon and Washington and, therefore, is subject to abatement under the provisions of the Federal Water Pollution Control Act.

RECOMMENDATIONS

Fiber and soluble organic material contribute to the damaging slime problem in the Columbia River. By far the greatest amounts of both causative agents are contained in pulp and paper mill wastes discharged to the river. To obtain progressive and continuing correction of this problem, the following waste control and treatment measures are recommended:

1. As a first step, all pulp and paper mills discharging wastes to the Columbia River should initiate the design and construction of mechanically cleaned primary treatment facilities for mill wastes. Such facilities should accomplish at least a 70 per cent reduction in volatile suspended matter discharged in untreated effluent. Volatile suspended matter discharged per day should not exceed those values shown in the column headed " . . . With Primary Treatment" in Table I. Adequate facilities for the disposal of recovered solids or sludge should also be provided. These new facilities to be provided at all of the mills should be completed and placed in operation no later than July 1, 1967.

2. Over half of the calculated BOD loading discharged to the Columbia River by the pulp and paper industry is contained in spent sulfite liquor discharged to the river at Camas and Vancouver, Washington, and that barged to the Columbia River from Oregon City, Oregon. A second progressive step to reduce waste loadings to the river will consist of a 70 per cent reduction in BOD loadings derived from sulfite liquor discharged at Camas and Vancouver, and elimination of liquor solids now barged to the Columbia River. The design of these remedial facilities should be completed by July 1, 1966, and the construction should be completed no later than December 31, 1967.

3. The remaining pollutional load reaching the river from the pulp and paper industry will consist of residual wastes from the several pulp and paper processes employed by individual mills located along this reach of the Columbia River. A continuing program of waste control will involve, in addition, the following:

a. Waste loadings, as shown in the last column of Table I, for individual mills should not be exceeded.

b. Additional wastes due to industrial expansion should be accompanied by provision for solids reduction, and a compensating degree of biological treatment, or other disposal means, to prevent exceeding the above recommended waste loadings.

c. Should the recommended measures contained in 1 and 2 above prove inadequate to prevent the development of objectionable slime growths in the Columbia River, then biological oxidation or other equally effective means will be necessary.

INTRODUCTION

In 1958, a conference (1) in the matter of pollution of the interstate waters of the Lower Columbia River was held under the provisions of Section 8 of the Federal Water Pollution Control Act. The conference was reconvened in 1959 to review progress made during the previous year and to adopt an action program (2) to establish a time schedule of remedial measures. The conferees, who were the Director of the Washington State Pollution Control Commission, the Secretary of the Oregon State Sanitary Authority, and the Assistant Regional Engineer (Region IX) of the U. S. Public Health Service, concluded that legitimate water uses were endangered by pollution and adopted the following water quality limits to conserve the waters for specified legitimate uses.

"Bacteria (Coliform): The limit of Coliform bacteria is as follows:

"A representative number of samples should average less than 240 per 100 milliliters and should not exceed this number in more than 20 percent of samples examined, when associated with domestic sewage.

"Solid materials discharged by municipal or industrial operations: The limit of such material is as follows:

"Floating, suspended, and settleable solids attributable /to/ sewage and industrial waste are limited to that remaining after primary treatment or its equivalent; and which, after

reasonable dilution and mixture with receiving waters, does not cause the formation of sludge beds and does not interfere with the specified legitimate uses.

"Slimes: The limit of such material is as follows:

"The presence of Sphaerotilus in such amounts that will /not/ interfere with specified legitimate uses.

"Toxic, colored, or other deleterious substances: The limit of such material is as follows:

"Substances alone or in combination with other substances or wastes, in sufficient amounts or of such nature as /not/ to make receiving waters unsafe or unsuitable for specified legitimate uses."

The following minimum treatment requirements for municipalities and industries were established by the conferees, as a part of an action program to sufficiently reduce pollution to meet the adopted quality limits:

1. All wastes shall receive a minimum of primary treatment or the equivalent thereof.

2. All sewage plant effluents shall be disinfected.

3. Nutrients which support Sphaerotilus growth shall be reduced to acceptable levels.

4. Toxic, colored, or other deleterious substances shall be limited to amounts that will not interfere with other water uses.

A Technical Coordinating Committee, consisting of a representative from the Oregon State Sanitary Authority, the Washington State Pollution

Control Commission, and the U. S. Public Health Service, was formed to implement an action program adopted by the conferees. It is the responsibility of this group to formulate plans for joint studies, to evaluate and recommend acceptance or rejection by the regulatory agencies of proposals for corrective measures, and to exchange technical information. Personnel from each of the agencies were assigned to undertake the joint field investigations.

The purpose of this report is to:

1. Summarize available information pertaining to the pollution problem of the Lower Columbia River.
2. Review the status of additional remedial measures taken since the 1958-59 Conference.
3. Recommend a course of action designed to correct the pollution problem.

Acknowledgment is made to the Oregon State Sanitary Authority and the Washington State Pollution Control Commission for their contribution of background and factual information from which the conclusions and recommendations of this report have been drawn.

Special recognition is given to Mr. Robert McHugh of the Oregon State Sanitary Authority for his contributions to a greater understanding of the Lower Columbia River slime problem.

While liberal use of information supplied by others has been made, this report is the sole responsibility of the U. S. Public Health Service.

AREA

The section of the Lower Columbia River from Bonneville Dam to Cathlamet, Washington, with which this report is concerned, is shown in Figure I. This 104-mile reach is more highly developed than any other comparable length of the main river.

Along this section of the river live more than a million people, of whom over three-fourths live in the metropolitan area of Portland, Oregon-Vancouver, Washington. Longview, Washington, is also one of the principal cities in the area. There is a total of ten sewered communities and several small miscellaneous sewerage systems.

Several types of manufacturing contribute toward a balanced economy for the region. Power produced from the river has brought many electro-metallurgical plants to the area. There are numerous food-processing plants. Diversified manufacturing and the service industries characteristic of a regional center are the principal supports of the Portland area. Wood products plants, which include the pulp and paper mills, constitute the major manufacturing industry for the entire area.

Income from fishing is important in the area's economy. The Columbia is justly famed for its salmon and steelhead trout. In fact, these two species of fish are so popular that most commercial and sport fishermen look with disdain on all other kinds of fish, even those which are highly prized in other sections of the country.

Excellent water transportation contributes to the prosperity of the area. Although Portland is over 100 miles from the ocean, the Columbia

makes it one of the important regional transportation and distribution centers of the Pacific Coast.

This section of the Columbia is subject to tidal action as far upstream as Bonneville Dam. The tidal range at Portland is small, not exceeding one foot. The flow in the Columbia River at Bonneville Dam usually varies from less than 100,000 cfs to over 400,000 cfs during the year. Normally there is a sharp increase in flow in May with maximum flow conditions occurring in June and July and a sharp decrease in flow in August. The remainder of the year the flow is usually nearly constant at about 100,000 cfs.

BACKGROUND

For more than 25 years the quality of the waters of the Lower Columbia River has been adversely affected by periodically abundant slime growths which flourish on nutrient materials contained in wastes discharged along the 80-mile stretch of the river between Camas and Cathlamet. The slime, called "pollution" by commercial fishermen, is a biological mass combined with varying amounts of fiber, debris, and sand. Sphaerotilus, a filamentous bacterium which usually predominates in the mass, serves as a matrix for the attachment of microscopic plants and animals and a mechanical adherent for the suspended debris. The severity of the problem varies with temperature, streamflow, and available wood fibers and nutrients.

The slime is detrimental to, and interferes with, legitimate water uses. The commercial fishermen's nets become coated with the slime, which reduces fishing efficiency. Commercial fishermen frequently must cease fishing or be highly selective in placing their nets to prevent having them swamped with slime. Fishermen report that fibers in the slime become entangled in the knots of their nets, making slime removal an extremely difficult and time-consuming operation.

Sport fishing is a very popular recreational activity on the Lower Columbia River. Slime interferes with this water use by fouling fishing gear and aggravating sports fishermen.

Water-contact recreation, such as skiing and swimming, has been adversely affected by waste discharges. Bacterial counts, mainly from domestic sewage discharges, have been above the maximum recommended for this type of activity. The large volumes of colored and turbid wastes

discharged to the river also adversely affect water-contact types of recreation. The aesthetic value of the stream is further deteriorated by biological growths which develop from the nutrients in waste discharges.

Initial attempts to control the slime problem resulted in the activation of state-agency programs with municipalities and industry. Municipal programs were directed toward the installation of waste treatment facilities. Industrial control programs were directed toward reduction of waste losses through in-plant controls and by the installation of storage lagoon facilities at one pulp mill.

Because of the magnitude of the pulp and paper industry problem, the need for intensified survey and research on all phases of waste abatement and treatment was recognized. Initially, in the late 1940's, efforts were directed to the construction of diffuser-type outfalls to achieve greater dispersion and dilution in order to reduce nutrient concentrations to a level that would not support slime growth. These outfalls had some reducing effect on localized slime growth, but the larger problem persisted. Based on laboratory research, which indicated slime-abatement possibilities by intermittent discharge of major nutrient-bearing wastes, Crown Zellerbach installed facilities to accomplish this method of control. Unfortunately, the slime problem continues to exist and is as severe as it was 25 years ago, if not worse.

REVIEW OF PAST STUDIES

Poor water quality in the Lower Columbia has prompted numerous studies, by both governmental agencies and industry, to define, evaluate, and propose measures to alleviate this problem. The following is a partial list of these studies and some of the pertinent observations that have been made.

In 1943, Lincoln and Foster (3) completed a seemingly exhaustive study of the slime problem. They concluded: "Waste sulfite liquor, and specifically the carbohydrates contained in the waste liquor, are the cause of the growth of Sphaerotilus in the Columbia River." Among other items, they also concluded that Sphaerotilus required a fixed surface on which to develop, that free-floating slime was that which had broken loose from such surfaces, and that "Sphaerotilus does not grow well in places where the concentration of waste sulfite liquor is below 50 ppm" (based on 10 per cent solids liquor, which is equivalent to 5 ppm based on 100 per cent solids liquor).

In 1951, the Washington State Pollution Control Commission conducted a study of the Lower Columbia River (4) and observed the growth of slime below all of the pulp and paper mills usually along the shore or on log rafts and noted suspended slimes occurred downstream from the observed localized areas of growth. The most profuse growth of Sphaerotilus was found near the Washington shore just downstream from the pulp mill in Vancouver.

Investigations made by the Oregon State Sanitary Authority, the Washington State Pollution Control Commission, and the U. S. Public Health Service in 1955, 1956, and 1957 (5) led to the conclusion that the pulp and paper mills are the major source of wastes which contribute to the production of slime in the river. The investigators also concluded that at times of freshet in the Willamette River, slime and associated nutrients enter the Columbia River and add to the problem.

In 1958, the report prepared by the U. S. Public Health Service (6) concluded that all evidence points to pulp and paper mill wastes as the

source of nutrients for the slime growths which occur from Camas to Cathlamet in quantities that interfere with fishing operations and other legitimate water uses.

Surveillance field studies were conducted by the U. S. Public Health Service from October 1958 to April 1960 (7). Tile boxes (8) and tow nets were used to determine the occurrence of slime. The report states, " . . . there was never any Sphaerotilus or associated slimes found at Sta. 1" (Washougal, above Camas, at R.M. 122.6).

Water quality data have been cooperatively collected since 1959 along the Lower Columbia River between Bonneville Dam and Cathlamet by the Washington State Pollution Control Commission, the Oregon State Sanitary Authority, and the Northwest Pulp and Paper Association together with the pulp mills located at Camas, Vancouver, St. Helens, and Longview; collection of the data is continuing at the present time. The purpose of this effort is to record the seasonal variation of water quality and slime growth in this section of the river. Following a statistical analysis of the data collected in 1960 by the University of Washington, Department of Civil Engineering (9), certain modifications were made in this program.

In 1960, Amberg and Cormack (10) concluded, after a three-year study, that the most important environmental factors for slime growth in the river appear to be velocity (0.4 to 2.0 fps), temperature (8^{o} to 16^{o} C.), and phosphate content. On the basis of laboratory results, they concluded that limited phosphate concentrations during the summer months may limit slime growth. Sphaerotilus will grow when spent sulfite solids concentrations are as low as 1 ppm (based on 100 per cent solids liquor, which is

equivalent to 10 ppm based on 10 per cent solids liquor) (0.2 ppm of BOD) within the velocity range. Their laboratory studies indicated that intermittent discharge greatly reduces the slime growth on fixed surfaces.

In 1962 the Oregon State Sanitary Authority, the Washington State Pollution Control Commission, and the U. S. Public Health Service (11), in a joint evaluation concluded that the intermittent discharge from Camas appeared to control slime growths in some reaches of the main stem of the river below the mill. However, slime problems still existed below Vancouver. Increases in the volume of slime collected in tow nets were attributed to growths that had been broken loose by increased river velocity. Substantial quantities of slime were collected on one occasion at Hewlett Point and were attributed to a flushing of the Willamette River, which was at flood stage.

A report prepared by Crown Zellerbach Corporation in 1963 (12) reviewed the development of the intermittent discharge system and their river observations between Camas and Skamokawa (R.M. 36, approximately) during discharge periods. They noted optimum slime growth occurred at a temperature range of about 10^{o} to 15^{o} C. and that growth may occur at temperatures below 10^{o} C., provided the growing period is sufficiently long. They reported that Sphaerotilus growth had been virtually eliminated between the Camas mill and the Interstate Bridge with intermittent discharge practices initiated by the company in late 1960. They also indicated that freshets were responsible for slime breaking loose and floating downstream. On the basis of their laboratory evaluations,

Sphaerotilus will grow when the spent sulfite solids concentration is as low as 2 and 5 ppm (based on 100 per cent solids). However, the amount of slime growth with the 2 ppm concentration is less than the amount of growth observed with higher concentrations.

A status report prepared in 1963 by the Oregon State Sanitary Authority, the Washington State Pollution Control Commission, and the U. S. Public Health Service (13) noted that all of the municipalities and industries, except the pulp and paper industry, had complied with the 1959 Action Program or had plans under way for remedial work. The report also noted that slime continued to be a problem in the river.

Prior to 1964, all of these investigators believed that most of the slime grew on fixed surfaces and broke loose to create problems downstream. Slime growth was observed on log rafts, pilings, and along the shore below the pulp mills. Tile boxes (8) were developed to provide attachment surfaces to determine slime growth potentials at selected locations. These earlier reports refer to the probability of large growing areas which would account for the large quantities of slime encountered by fishermen during critical times. In addition, these earlier studies contributed the following:

1. The carbohydrates contained in waste sulfite liquor are the principal nutrient associated with the growth of Sphaerotilus and associated biological mass in the Columbia River.

2. One investigator (12) noted that the optimum temperature range for slime growth in the river is about 10-15° C.

3. Slime will develop when the spent sulfite solids liquor concentration is as low as 1 and 2 ppm (based on 100 per cent solids), but the quantity of slime growth is not as great as at higher concentrations.

4. Low concentrations of phosphates and nitrates, in addition to carbohydrates, are essential nutrients for growth of Sphaerotilus.

5. Slime interferes with commercial and sport fishing.

6. The slime problem is more severe during low-flow periods in the spring and fall.

7. Slime with a high fiber content is more difficult to remove from fishermen's nets. A combination of fresh slime and fiber is the most difficult to remove.

8. More slime is caught on diver nets than on floater nets in the ship channel portion of the river from Kalama downstream. This indicates the slime is slightly heavier than water and is carried near the bottom in the deeper parts of the river.

9. During flood conditions the Willamette River and Multnomah Channel contribute fiber, detritus, and nutrients to the Columbia River.

WILLAMETTE RIVER

Judging from past studies, the magnitude and effect of the pollutional material in the Willamette River on the Columbia River have not been fully evaluated. Previous investigators have tended to treat the oxygen deficiency in Portland Harbor, caused by upstream waste discharges, and the slime problem in the Columbia River as separate problems. Flow variations in the two rivers coupled with the distribution of flow to the main stem of the Willamette River and Multnomah Channel suggest extensive

studies would be required for a definitive answer. At various times sport fishermen have complained about tainted fish caught in the lower part of the Willamette River and Multnomah Channel. Investigations in 1965 indicate the problem is related to the discharge of industrial wastes to the river under low-flow conditions. The extent of the problem and the effects on the Columbia River have not been adequately explored.

WATER USES

The Lower Columbia River supports a wide variety of water uses and has a considerable influence on the area's economic, recreational, and aesthetic activities. Uses are generally growing at a rate exceeding the rate of population growth. The following examination provides a basis for evaluating the magnitude and importance of the various uses. Values and quantities have been used, where applicable, but these are not intended to be all-inclusive. They serve only to place the relative importance of the uses in proper perspective.

WATER SUPPLY

Municipal and industrial water supply is not presently a major use of the Lower Columbia River. One small village downstream from Puget Island and two industries withdraw water from this portion of the river. Although the village is not within the section of the river dealt with in the report, its source is subjected to bacterial contamination from upstream waste outfalls.

The Weyerhaeuser Timber Company and the Longview Fibre Company pulp and paper mills at Longview, Washington, use the Columbia River as a water source. Weyerhaeuser pumps over 100 million gallons per day (mgd) from the river; the water is treated for industrial as well as domestic use by the company. Longview Fibre Company withdraws over 50 mgd. Other known industrial supplies taken from the Columbia are quite small.

RECREATION

Because of its proximity to the Portland-Vancouver urban area and

because of the influx of summer tourists, the Lower Columbia is heavily used for water-contact sports and recreation. Other than game fishing, recreational water uses include boating, swimming, skin-diving, water-skiing, and picnicking. Streamside picnicking and camping, with accompanying boating and swimming, are popular family weekend outings.

Statistics are only partially available to measure the demand for recreation, and these are more useful as an index of trends rather than as an indication of the overall dimensions of a particular recreational use. In order to quantify recreational use of water, it is necessary that the use be reasonably well organized and subject to some type of control. It must be recognized, however, that a great deal of recreation is on an informal basis, which makes evaluation difficult.

Pleasure Boating

There are numerous boat moorages on the Lower Columbia River. A major concentration of moorages extends along the Oregon bank from near the lower end of Government Island to below Interstate Bridge, which includes the Jantzen Beach Park and Marina on Hayden Island. Other main river moorages on the Oregon side are at St. Helens and Rainier. On the Washington side, there are moorages just above Camas, at Vancouver, near the mouth of the Cowlitz River at Longview, near Stella, and at Cathlamet.

The Oregon State Marine Board registers all Oregon boats by county. The three Oregon counties adjacent to the lower portion of the Columbia have licensed 15,900 boats of varying sizes. Although Washington does not register boats by county, the Oregon Marine Board has estimated that the four counties in Washington bordering the Columbia have over 6,300

boats. This figure was calculated using the national average of boats per population and is therefore conservative. It is estimated that between 22,000 and 25,000 boats use the Columbia River for at least a part of the year.

Swimming

Much of the swimming and water-skiing in the Lower Columbia is upstream from the Portland-Vancouver urban area. One of the most popular river beaches is at Rooster Rock State Park about 25 miles east of Portland. Based on car counter statistics, over 155,000 persons visited this one park in July and August of 1964, with peak days running as high as 15,000. Other water-sport areas are in the vicinity of the boat moorages which extend upstream to Government Island, and in the vicinity of Jantzen Beach on Hayden Island, just above the Interstate Bridge.

Statistics indicate a decrease in the number of swimmers in the Portland-Vancouver area. Reeder Beach on Sauvie Island, about eight miles below the Portland sewage plant outfall, is a center of water recreation; and there are other, less organized uses of the river for swimming and water-skiing downstream to Cathlamet. Small groups are frequently observed throughout the lower section of the main river even though the river is subject to some bacterial contamination from municipal outfalls.

Hunting

The Lower Columbia provides many inlets and good cover for duck hunting, both from the land and by boat. Statistics are not available to measure the extent of this sport for the entire Lower Columbia, but

counts from the game preserve on Sauvie Island indicate the popularity of the area. In 1964, over 10,000 hunter-days were recorded in this one area.

FISHERY RESOURCES

One of the outstanding uses of the Columbia River is the sport and commercial fishery. The Columbia and its tributaries contain large populations of salmon and steelhead, highly prized by sport anglers and commercial fishermen alike. The river also provides spawning areas and passage for these migratory fish, so the value of the fishery attributable to the Columbia River is considerable. Migration and spawning of the salmonid species in the upper reaches of the Columbia are so important that special fish passage facilities have been constructed to permit the fish to move past Bonneville and other upstream dams.

Sport Fishery

An intensive salmon and steelhead sport fishery occurs in and adjacent to the mouth of the Columbia River each year. The Bureau of Commercial Fisheries is currently making a study of the value of the sport fishery attributable to the Columbia River. Preliminary figures, subject to revision when tagging studies are completed, indicate that in 1964 a total of 1.3 million fisherman-days were expended to catch over 400,000 salmon and steelhead in the ocean and the river. The gross value of the sport fishery has been estimated to be about $20,000,000.

Commercial Fishery

Although the commercial fishery in the Columbia has been decreasing for several years due to restriction by the States involved, a considerable

commercial value is attributable to the Columbia. Preliminary estimates by the Bureau of Commercial Fisheries indicate gross sales by fishermen in 1964 at about $6,000,000.

In 1964, 689 gill net licenses were issued to Columbia River fishermen in Washington and Oregon. There are more ocean-troll commercial fishing licenses issued than gill net licenses. Approximately 13 million pounds of all species of salmon attributable to the Columbia River were caught in the ocean and the river. In addition, about 1-1/4 million pounds of shad, smelt, and sturgeon were caught in the Columbia for the commercial market.

HYDROELECTRIC POWER PRODUCTION

The power plant at Bonneville is the only hydroelectric power facility in this section of the Lower Columbia. It has a total rated capacity of approximately 518,400 kilowatts and produces an important portion of the total power produced in the Columbia River Basin.

Bonneville Dam is also used to control the flow in the Lower Columbia River. Although Bonneville Pool provides little storage and has relatively little effect on the average daily flow of the river, the hourly flow can be regulated, especially during times of low flow, by operation of the generators for peak power conditions.

IRRIGATION

Although irrigation is a major use of the upper reaches of the river, there is only a small amount of irrigated land along the Lower Columbia. Irrigation water is pumped from the river at 25 to 30 points between

Bonneville Dam and Cathlamet and is used principally to irrigate vegetable produce. Sauvie Island is the primary section of cropland irrigated from the Lower Columbia.

NAVIGATION

Portland, Oregon, is the largest fresh water port in the world. Since 1955, shipments handled in the Columbia and Willamette Rivers have totaled 20 million tons every year but one. The Port of Portland handles a tonnage equivalent to, and in recent years greater than, that of Seattle, thus ranking it the third largest port on the West Coast. Portland is one of the largest grain ports in the country.

In addition to those at Portland, there are extensive dock facilities at Vancouver and Longview, and future development can be expected near Wauna with the completion of the new pulp and paper complex presently under construction. Intercoastal transportation is growing rapidly with the completion of harbor facilities in coastal streams.

Large numbers of log rafts are transported on the river for the lumber and pulp and paper plants in the area. The logs, while awaiting use, are stored in quiet areas along the river banks and in sloughs on either side of the river. Most of the storage areas are between Camas and Cathlamet, Washington, with only a limited amount of storage between Camas and Bonneville Dam.

PRESENT WASTE SOURCES

The locations of the waste sources involved in this report are shown in Figure II on page 38.

MUNICIPAL

All of the following municipalities have sewage treatment plants which provide primary sedimentation and effluent disinfection:

Oregon	Washington
Clatskanie	Cathlamet
Rainier	Longview
St. Helens	Kalama
Portland	Vancouver
Portland Airport	Camas
Gresham	

The effluent from all of these plants is discharged to the Columbia River. The details pertaining to wastes from these municipalities are summarized in Table II on page 39.

INDUSTRIAL

Details pertaining to all the sources of industrial wastes involved in this report are summarized in Table III on page 40.

Grain Washing

Washing of grain to remove foreign or undesired matter is employed at Continental Grain Company, Longview; North Pacific Grain Growers, Inc., Kalama; and Archer-Daniels-Midland, Vancouver. Waste matter from this operation consists of cracked or crushed grain, smut, chaff, and weeds. Until early 1964, these wastes were discharged directly to the Columbia River. Since that time, the wastes have been collected by screening (50 mesh) and utilized for animal feed or disposed of on land. Some grain does not require washing and, as a result, waste discharges fluctuate.

The liquid portions of the wastes are discharged to the river through submerged outfalls.

Food Processing

Solid and liquid wastes result from processing of fruit and vegetables at California Packing Company and Washington Canners at Vancouver. Solid wastes consist of peelings, pits, seeds, and culls, while liquid wastes contain dissolved organic material. By use of sumps and screens, the solid wastes are collected and disposed of on land. The liquid wastes pass 20-mesh screens and are then discharged to the Columbia River through a submerged outfall. Sanitary sewage is discharged to the city sewer system.

Malting and Brewing

The Great Western Malting Company, Vancouver, produces malt used in the brewing industry. The primary source of process waste results from a grain-steeping operation in which steeping liquid is drained. These wastes are screened (20 mesh) before being discharged to the Columbia River. Spent grains are collected and used for animal feed. Sanitary sewage is discharged to the city sewer system.

The Lucky Lager Brewery, Vancouver, collects spent brewing grain, hops, and surplus yeast to be used as animal feed or fertilizer. Process and clean-up wastes and spoiled beer are screened prior to discharge to the city sewer system along with the sanitary sewage.

Pulp and Paper

Details pertaining to the reported pulp and paper production for the mills discussed in this section are summarized in Table IV on page 41.

The Weyerhaeuser Timber Company, Longview, operates a 1,160 ton/day pulp mill, of which 725 tons are produced by the sulfate process, 325 tons by the sulfite process, and 110 tons by the semi-chemical pulping process. From this pulping operation, 925 tons/day of bleached pulp are produced. Paper production is 470 tons/day and the remaining pulp is sold. In 1948, this mill converted its calcium base sulfite mill into a magnesium base sulfite mill, with evaporation and burning of the concentrated cooking liquors for recovery of the magnesium oxide. The sulfate and semi-chemical pulping operations also have an integrated base recovery system. Savealls are used to recover fiber from the paper machine white water streams. Waste water from the hydraulic barker is clarified in a settling basin to remove settleable solids. Monthly effluent loss reports have been submitted to the Washington State Pollution Control Commission since 1956 and presently include solids and BOD losses. The reported 1964 losses discharged to the Columbia River were 59,000 pounds/day of VSM and 150,000 pounds/day of BOD in an average effluent flow of 101 million gallons per day (mgd). Sanitary sewage is treated at the mill's primary treatment plant, and the effluent is chlorinated. The sanitary and mill process wastes are combined and discharged through a submerged diffuser outfall into the Columbia River.

The Longview Fibre Company, Longview, produces 1,270 tons/day of pulp, of which 1,160 tons are produced by the sulfate process, 25 tons by the groundwood process, and 85 tons by the semi-chemical pulping process. From this pulping operation, 220 tons/day of bleached pulp are produced. In addition, 1,260 tons/day of paper are produced. This mill

incorporates evaporation and burning of the concentrated cooking liquors for recovery of the base chemicals. Also, a portion of the evaporator condensate is processed and the chemicals are reused. Savealls are utilized to reclaim fibers from the paper machine white water streams. Effluents from the groundwood operation are almost entirely reused in other mill processes. Monthly effluent loss reports have been submitted to the Washington State Pollution Control Commission since 1956, and present reports include solids and BOD losses. Reported 1964 losses to the Columbia River were 47,500 pounds/day of VSM and 80,000 pounds/day of BOD in an average effluent flow of 51 mgd. The mill operates its own primary sanitary sewage treatment plant and chlorinates the effluent. The sanitary sewage effluent and mill effluent are combined and discharged through a single submerged diffuser outfall into the Columbia River.

The Boise-Cascade Paper Corporation (formerly Crown Zellerbach Corporation), St. Helens, Oregon, produces 396 tons/day of sulfate pulp. From this pulping operation, 291 tons/day of bleached pulp are produced. In addition, 361 tons/day of paper are produced. The mill effluent is discharged into Multnomah Channel about one-quarter of a mile upstream from its confluence with the Columbia River. This discharge point is approximately midway between the entrance of Scappoose Bay to Multnomah Channel and the confluence of the channel with the Columbia River. Evaporation and burning of concentrated waste liquors for recovery of base material are practiced. Savealls are utilized to recover usable fibers from the paper machine white water streams. Mill waste loading data have been submitted to the Oregon State Sanitary Authority since

September 1959 except during the times the Columbia River floods and submerges the sampling weir. Reported 1964 average losses to Multnomah Channel were 40,100 pounds/day total suspended matter (TSM) and 23,250 pounds/day of BOD in an average volume of mill effluent of 26.3 mgd. Septic tanks with underground absorption fields are utilized for the disposal of sanitary sewage.

The Kaiser Gypsum Company, St. Helens, Oregon, operates a 165 ton/day groundwood pulp mill, which produces 438 thousand square feet per day of one-half-inch-stock softboard. The three waste discharge points are all located near the mouth of McNulty Bay, about three-quarters of a mile upstream from the Scappoose Bay entrance to Multnomah Channel. Weekly data on BOD and suspended solids loadings have been reported to the State Sanitary Authority by the Kaiser Gypsum Company since 1960. In 1964 the reported average losses were 7,025 pounds/day of BOD and 8,575 pounds/day TSM. The mill effluent averages 1.4 mgd. More efficient new equipment is being installed to replace older equipment, and this should reduce waste losses. The company has initiated a continuing waste reduction program through the recovery of all usable fiber by water reuse. Septic tanks with underground absorption fields are utilized for the disposal of sanitary sewage.

The Publishers Paper Company, Oregon City, Oregon, produces 452 tons/day of pulp, of which 295 tons are produced by the groundwood process and 157 tons by the sulfite process. There is no recovery of base material from the concentrated waste liquor. During the critical flow season in the Willamette River, usually from June to November, the

company barges concentrated spent sulfite liquor for discharge into the Columbia River below the junction of the Willamette River. This practice was initiated in 1953. The 1964 average BOD load discharged to the Columbia River between June 29 and November 1 was 60,000 pounds/day in an average volume of 373,600 gallons/day.

The Boise-Cascade Paper Corporation (formerly the Columbia River Paper Mill), Vancouver, operates a 165 ton/day sulfite mill. Bleached pulp production is 159 tons/day. About 171 tons of fine writing and specialty paper are produced per day. There is no recovery of base chemicals from concentrated cooking liquors at this mill. Savealls are used to recover usable fibers from paper machine white waters. Effluent loss reports have been submitted monthly to the Washington State Pollution Control Commission since 1956 and include solids losses. Reported VSM losses in 1964 averaged 16,200 pounds/day. The 1964 BOD losses were estimated to be 133,000 pounds/day. An average of 15.3 mgd of mill effluent is discharged into the Columbia River through a deep water diffuser outfall installed in 1964. Sanitary sewage is discharged to the City of Vancouver collection system for treatment.

The Crown Zellerbach Corporation, Camas, operates a 1,190 ton/day pulp mill, of which 745 tons are produced by the sulfate process, 420 tons by the sulfite process, and 25 tons by the groundwood pulping process. From this pulping operation, 940 tons/day of bleached pulp are produced. In addition, 1,040 tons/day of paper and tissue products are produced. The conventional evaporation and burning recovery system is utilized for the sulfate process. Savealls are used to recover usable fibers from the paper machine white waters. Groundwood mill effluents are essentially reused in other mill operations. Monthly

effluent loss reports have been submitted to the Washington State Pollution Control Commission since 1956 and include solids losses from the various operations. Reported 1964 VSM losses to the Columbia River averaged 81,000 pounds/day. BOD losses were estimated to be 325,000 pounds/day, of which 280,000 pounds/day were stored in a 46-acre holding lagoon on Lady Island. The pond was normally discharged to the Columbia River through a submerged outfall every seventh day and represented a BOD discharge for that day of 1,960,000 pounds. The remaining 45,000 pounds of BOD were discharged daily to the river through a submerged outfall. Sanitary sewage from the mill is treated at the City of Camas sewage treatment plant.

The mill lagoon is capable of storing 85 per cent of the sulfite liquors for a period of 60 days. In 1965, the mill stored this amount of liquor during the usually severe slime growth season of April and May.

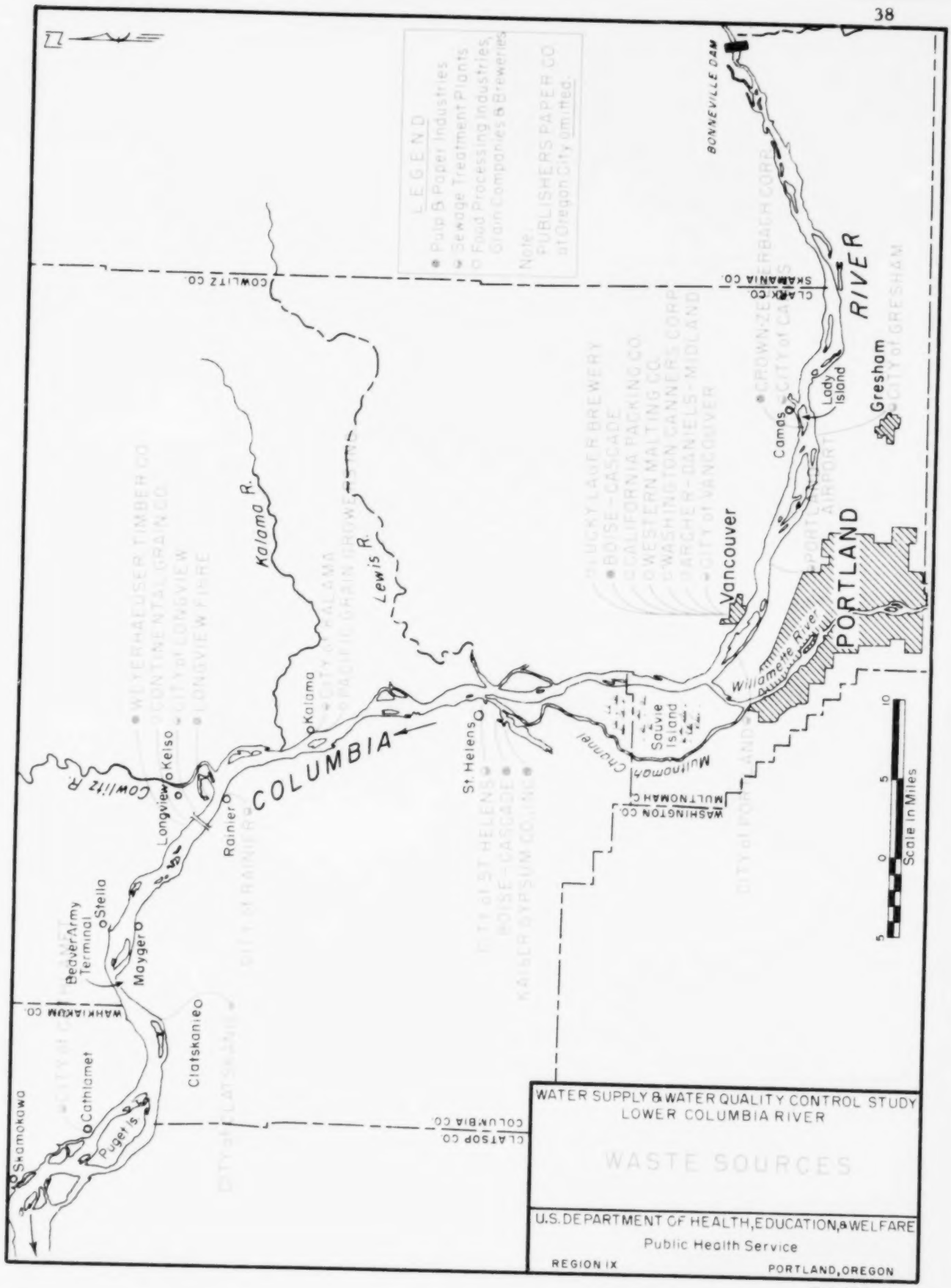
LEGEND
Pulp & Paper Industries
Sewage Treatment Plants
Food Processing Industries, Grain Companies & Breweries
Note: PUBLISHERS PAPER CO at Oregon City, omitted.
BONNEVILLE DAM
COWLITZ CO.
SKAMANIA CO.
CLARK CO.
RIVER
Gresham
Lady Island
Camas
Vancouver
PORTLAND
Kalama R.
Lewis R.
Willamette River
Sauvie Island
Multnomah Channel
Kalama
St. Helens
COLUMBIA
Cowlitz R.
Kelso
Longview
Rainier
WASHINGTON CO.
MULTNOMAH CO.
Beaver Army Terminal
Stella
Mayger
WAHKIAKUM CO.
Clatskanie
Cathlamet
Puget Is.
Skamokawa
COLUMBIA CO.
CLATSOP CO.
Scale in Miles
0
5
10
WATER SUPPLY & WATER QUALITY CONTROL STUDY
LOWER COLUMBIA RIVER
WASTE SOURCES
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX
PORTLAND, OREGON

FIGURE II

TABLE II
MUNICIPAL WASTES

City	River Mile	Estimated Connected Population		Est. Lbs. BOD/day Treatment Plant Effluent		Est. Lbs. VSM/day[a] Treatment Plant Effluent		Est. Volume MGD		Type of Treatment
		1959	1964	1959	1964	1959	1964	1959	1964	
Cathlamet, Wash.	40	400	500	70	85		75		0.06	Lagoon and chlorination.
Clatskanie, Oreg.	49	800	800	90	90		80		0.3	Primary settling and chlorination.
Longview, Wash.	66	20,000	22,700	2,250	2,500		2,000		2.5	Same as above.
Rainier, Oreg.	67	1,200	1,200	135	135		120		0.2	Same as above.
Kalama, Wash.	74	425	450	45	50		40		0.05	Same as above.
St. Helens, Oreg.	86	4,500	4,960	500	550		490		1.2	Same as above.
Portland, Oreg.	105.5	280,000	370,000	45,000	42,750		36,500		62.0	Same as above.
Vancouver, Wash.	106	30,000	31,800	3,700	3,500		2,800		3.5	Same as above.
Portland Airport	110	3,000	3,000	330	330		30		0.4	Same as above.
Gresham, Oreg.	117.7	3,000	4,500	330	495		50		2.0	Same as above.
Camas, Wash.	118	4,400	4,550	475	500		400		0.7	Same as above.
TOTAL		347,725	444,460	52,925	50,985		42,585		72.91	

a/ Volatile Suspended Matter

TABLE III
INDUSTRIAL WASTES

	Est. Lbs. BOD Per Day		Est. Population Equivalent[a] for BOD Per Day		Est. Lbs. VSS[b] Per Day		Est. Volume MGD		Total Solids Per Day	
	1959	1964	1959	1964	1959	1964	1959	1964	1959	1964
Grain Storage										
Continental Grain Co.	1,500	400	8,800	2,400		300		0.750		
N. Pacific Grain Growers, Inc.	1,500	400	8,800	2,400		300		0.500		
Archer-Daniels-Midland	1,500	400	8,800	2,400		300		0.475		
Food Processing										
California Packing Co.	13,400	15,000	78,800	88,200		1,500		1.3		
Washington Canners	3,640	14,000	21,000	82,000		1,400		0.29		
Malting and Brewing										
Great Western Malting Co.	2,600	2,500	15,300	14,700		Negligible		3.6		
Lucky Lager Brewery	3,000	2,500	17,600	14,700		Negligible		1.0		
Totals	27,140	35,200	159,100	206,800		3,800		7.915		
Pulp and Paper										
Weyerhaeuser Timber Co.	130,000	150,000	765,000	882,000	36,800	59,000	75	101	640,000	921,000
Longview Fibre Co.	46,000	80,000	271,000	471,000	35,700	47,500	36	51	156,000	274,000
Boise-Cascade, St. Helens	[c]	23,250	[c]	137,000	50,100[d]	40,100[d]	26	26.3	[c]	[c]
Kaiser Gypsum Co.	[c]	7,025	[c]	41,300	[c]	8,575[d]	[c]	1.4	[c]	[c]
Publishers Paper Co.[e]	[c]	60,000	[c]	353,000	---	---	0.33	0.37	220,000	392,000
Boise-Cascade, Vancouver	105,000	133,000	618,000	782,000	12,800	16,200	13.2	15.3	260,000	326,000
Crown Zellerbach	260,000	325,000	1,530,000	1,910,000	62,000	81,000	126	148	1,275,000	1,750,000
Totals	541,000	778,275	3,184,000	4,576,300	197,400	252,375	276.53	343.37	2,551,000	3,663,000

a/ Population equivalent based on 0.17 lb. BOD/capita.
b/ Volatile suspended matter.
c/ No data available.
d/ Total suspended matter.
e/ Reported figures pertain only to wastes barged to the Columbia River from 6/22/59 to 10/31/59 and from 6/29/64 to 11/1/64.

TABLE IV
REPORTED PULP AND PAPER PRODUCTION
LOWER COLUMBIA RIVER AND MULTNOMAH CHANNEL

Plant	Pulp - Tons/Day												Paper - Tons/Day	
	Sulfite		Sulfate		Semi-Chemical		Groundwood		Total Pulp Production		Total Bleached Pulp Production		Paper Production	
	1959	1964	1959	1964	1959	1964	1959	1964	1959	1964	1959	1964	1959	1964
Weyerhaeuser Timber Co., Longview, Wn.	260	325	490	725	176	110			926	1,160	690	925	430	470
Longview Fibre Co. Longview, Wn.			845	1,160	59	85	21	25	925	1,270	123	220	920	1,260
Boise-Cascade Paper Corporation St. Helens, Ore.			358	396					358	396	258	291	326	361
Kaiser Gypsum Co. St. Helens, Ore.							145[a]	165	145	165	None	None	None	None
Publishers Paper Co. Oregon City, Ore.	119	157					195[a]	295	314	452	b/	b/	b/	b/
Boise-Cascade Paper Corporation Vancouver, Wn.	132	165							132	165	125	159	134	171
Crown Zellerbach Corp. Camas, Wn.	370	420	580	745			26	25	976	1,190	670	940	865	1,040
Totals	881	1,067	2,273	3,026	235	195	387	510	3,776	4,798	1,866	2,535	2,675	3,302

a/ Lockwood Directory of the Pulp and Paper Industry.

b/ Production not directly applicable to Columbia River.

PROGRESS IN POLLUTION ABATEMENT SINCE 1958-59 CONFERENCE

STATE ACTION

Following the 1959 Conference, the States of Oregon and Washington, with the support of the Technical Coordinating Committee, initiated a cooperative pollution-abatement program to accomplish the objectives of the Conference. The Oregon State Sanitary Authority had to institute legal proceedings before the City of Portland agreed to install chlorination facilities at the city's sewage treatment plant. Late in 1959, St. Helens, Oregon, completed a new sewage treatment plant with the assistance of a Public Law 660 grant approved by the Oregon State Sanitary Authority. The construction of intercepting sewers in Vancouver and of a new treatment plant in Cathlamet required considerable effort on the part of the Washington State Pollution Control Commission in addition to Public Law 660 financial assistance. The Washington State Pollution Control Commission also worked with the three grain companies in Longview, Kalama, and Vancouver in the development and construction of screening equipment to treat grain-washing wastes.

The Technical Coordinating Committee agreed to delay upgrading requirements for the pulp and paper industry until evaluations could be made of the intermittent discharge method of disposal at Camas and the effect at all the mills of in-plant process changes on waste discharged to the river. Crown Zellerbach, Weyerhaeuser, and Longview Fibre have valid waste discharge permits which expire December 4, 1967; August 15, 1968; and February 14, 1969, respectively. These permits, which are subject to upgrading, do

not require primary sedimentation or biological treatment of the wastes at the present time. The permit for the Boise-Cascade mill at Vancouver has expired and has not been renewed.

Although no deadline has been established, the Oregon State Sanitary Authority has requested the Boise-Cascade Paper Corporation to reduce its fiber and BOD losses at its St. Helens mill and to study methods of solids reduction by primary treatment. The Kaiser Gypsum Company likewise has been requested to reduce its fiber and BOD losses sufficiently to abate the pollution of Scappoose Bay. The latter company has reportedly already reduced its BOD loadings by more than 56 per cent and has plans under way for effecting further reductions.

By 1964 it became apparent that the slime problem resulting from both the intermittent waste discharge practice and the losses of wood fibers to the river was such that the water quality limits adopted by the conferees in 1959 were being exceeded. On the basis of this observation, the Public Health Service wrote both State regulatory agencies on June 1, 1964, stressing the need to upgrade the waste disposal requirements of the pulp and paper mills and suggesting that an enforcement hearing be called to accomplish needed improvements. As a result, representatives of the Washington State Pollution Control Commission visited each of the mills in the State of Washington to discuss the upgrading of treatment requirements.

MUNICIPAL

All of the cities and towns provide at least primary treatment with effluent disinfection, with improvements having been made at St. Helens, Portland, and Vancouver since 1959. New facilities at Cathlamet, Washington,

were completed and placed in operation in 1965. Consequently, the municipalities have complied with minimum treatment requirements adopted by the Conference. However, this progress does not preclude the need for additional improvements to collection systems and treatment plants to prevent bypassing of raw sewage to the river either from infiltration during wet weather or from overloading the facilities due to growth of the city. Continual maintenance is required to cope with sewer infiltration problems.

A bacteriological survey of the Columbia River in the Portland-Vancouver area was completed in September 1964. The results of this survey (14), when compared with similar surveys in 1960, 1962, and 1963, show a great reduction in coliform bacteria. The bacterial quality of the Columbia River now closely approaches the standards adopted by the Conference.

In the Portland area, raw sewage or untreated industrial wastes are still being discharged into the Willamette River from some 27 city-owned and 25 private sewers (15). In 1963 these discharges had a population equivalent of 112,000. During 1964 a number of these sewers were intercepted, and the population equivalent of the untreated discharge is now 28,000. A deadline of December 1967 has been established by the Oregon State Sanitary Authority for the installation of sewage and waste-treatment facilities by all cities and industries discharging wastes to the Willamette River to provide secondary treatment which will remove not less than 85 per cent of the BOD and TSM. Although Portland has spent some 20 million dollars since 1947 for the construction of interceptor sewers and treatment works, another 11 to 19 million dollars is needed to complete the job of abating its share of the pollution in the Willamette.

Houseboats also discharge raw sewage to the river. The regulatory agencies have undertaken a study to determine the extent of the problem and to find a satisfactory solution. The State of Oregon enacted a new legal statute during the 1965 Legislature to regulate the discharge of these wastes.

INDUSTRIAL

The Technical Coordinating Committee has determined that all of the industries discharging wastes directly to the Lower Columbia River have complied with the minimum treatment requirements adopted by the Conference, except the pulp and paper industry. The three grain elevators now have screening facilities to prevent the discharge of waste grain to the river. The two food-processing plants separate their solid wastes and screen their process waters in order to minimize the discharge of objectionable waste solids to the river. Both the malting plant and the brewery either have screening facilities to prevent the entrance of solid wastes into the river or discharge their wastes to the city sewer system.

Following the 1959 Conference, Crown Zellerbach Corporation at Camas proposed the construction of a waste-holding pond for intermittent discharge of its concentrated wastes. The proposal was based on company laboratory research which indicated Sphaerotilus would not grow and develop to any extent on a fixed surface exposed to waste liquors only one day each week. The company placed its 46-acre holding pond in operation late in 1960. An initial evaluation of this method had shown a reduction in the slime problem between Camas and Vancouver.

Based on this initial evaluation, the Columbia River Paper Mill, Vancouver, on October 10, 1961, proposed construction of waste-holding facilities. In 1962 the Technical Coordinating Committee conducted an evaluation study, and the Washington State Pollution Control Commission made an in-plant survey before approval was given to this proposal. Before plans could be completed and approved, the mill was sold to Boise-Cascade, which on September 10, 1963, proposed evaporation and burning of its wastes and other changes as a more effective answer to its waste problem. The waste outfall was extended 580 feet into the river during April and May 1964 as a preliminary step to the installation of equipment for the reduction of slime growth in the river.

The delay in effecting progress in the elimination of the slime problem is the result of the pulp and paper industry's attempt to find a substitute for waste treatment and their desire to more fully evaluate the effectiveness of substitute measures to control slime growths in the river. Consequently, progress in correcting pollution caused by these mills has been minimal since the Conference.

COMPARISON OF 1959 AND 1964 WASTE LOADINGS

Since 1959, the average daily BOD load discharged to the Columbia River from all sources of wastes has increased over 165,000* pounds/day--an increase of 25 per cent. The loading from the pulp and paper industry has increased 27 per cent and represents 96 per cent of the total increase in BOD loadings during the five-year period. While the other industries

*The BOD increase for the three Oregon mills has been calculated in proportion to the increase in pulp production and represents about 10 per cent of the total.

show a 30 per cent increase in BOD loadings, this amount represents less than five per cent of the total increase. The BOD load imposed by the municipalities has decreased slightly during this period.

Between 1959 and 1964, pulp production for all of the mills has increased 27 per cent (1,022 tons/day), while paper production has increased 23 per cent (627 tons/day). The greatest increase in daily BOD and VSM loadings to the river has been in the Longview area. The pulp production capacity in this area has increased 579 tons/day, or 31 per cent. Paper production has also increased 380 tons, or 28 per cent. The corresponding increases in BOD and VSM loadings to the river are 31 per cent and 47 per cent, respectively. In the Vancouver area the increase in both BOD and VSM loadings to the river from the pulp and paper mill wastes has been 27 per cent. In the Camas area the average daily BOD produced has increased 25 per cent, while the VSM discharged to the river has increased about 31 per cent. While the intermittent discharge practice at Camas has resulted in decreased BOD loading to the river six days a week, when compared with 1959, the large 1,960,000 pound "slug" of BOD discharged from the holding pond on the seventh day actually represents a 25 per cent increase in loading when considered on the weekly basis.

EFFECTS OF WASTE ON WATER QUALITY AND USES

RIVER SURVEY, 1964

Early in 1964, Mr. Robert McHugh of the Oregon State Sanitary Authority had completed translation of German literature relating to similar slime problems (16). The German observers report slime will develop and grow on suspended debris in large, deep rivers. On the basis of this finding and the abundance of slime reported by fishermen during snagging operations in February and March, a limited sampling program was undertaken by representatives of the Oregon State Sanitary Authority, Washington State Pollution Control Commission, and the U. S. Public Health Service during April and May. Sampling equipment, similar to that reported in German literature, was used to collect samples from different depths and locations. Details pertaining to the equipment and sampling procedures are included in Appendix A, and commercial fishermen's drifts are shown in Figure III. The results of the sample analyses are given in Appendix B. These samples show the existence of fiber in both the Columbia River and Multnomah Channel and the growth of Sphaerotilus and other biota.

BIOLOGICAL OBSERVATIONS, 1964

In addition to the sampling program, Mr. McHugh made biological observations of the slime problem during the fishermen's snagging and fishing operations. The biological evaluation of the slime problem in the river is as follows:

Nature of Slime Deposits

In the lower river, from Clatskanie to the bay, slime removed from gill nets consists largely of wood fibers, stuck together by a dark,

amorphous material resembling decomposed Sphaerotilus. Up to 15 per cent of the volume was composed of algae, mostly diatoms, with some filamentous algae usually found growing attached to log rafts, pilings, and stones. The algae give the slime a dark-green color, and, as some diatoms themselves secrete a mucilaginous covering, may contribute to the sticking together of the fibers. No fresh, recognizable filaments of Sphaerotilus usually occur, although there have been reports of masses of light-yellowish biological masses in this area, which may well have been growing slime bacteria. At least two of the samples collected from fishermen's nets at Clatskanie during the fall 1964 season contained small amounts of new, growing Sphaerotilus. The origin of this material is not known.

From approximately Rainier to Vancouver, the percentage of wood fibers in the biological masses diminishes, and more than half of the fibrous content may consist of fragments of grass, leaves, and other organic trash on which filaments of growing Sphaerotilus may grow. There are also much dark, decomposed slime and some algae present. Many of the leaf and grass fragments were so heavily overgrown by mycelia of water molds (Phycomycetes) that the mycelia comprised a definite part of the volume of organic matter. Water molds attack and disintegrate specific organic substrates; some attack live plants, some dead plants; some attack algae; others only the cast skins of insects, etc. During the sampling in the Stella area (May 15-16, 1964), an experimental gill net was drifted near the bottom and became heavily coated with slime which included much plant debris, some wood fiber, and Sphaerotilus. On drying, almost all of the slime crumbled off the net in the form of a fine powder, possibly because the organic substrates had been

nearly disintegrated by the action of water molds and bacteria. Upriver from Vancouver, gill net fishermen have generally not complained of slime problems, although the "slug" of lagooned waste periodically released from the Camas lagoon passes through these drifts. It is the general practice of the fishermen not to fish during the time this discharge is passing through the area.

During the period April 1-8, 1964, a break occurred in a pipeline at Camas, and during this nine-day period an estimated 20 per cent of the sulfite liquor escaped into the river as a continuous discharge. The last day on which leakage occurred was the 8th. Following repair of the leak, all wastes were ponded until the 12th, when the lagoon was discharged. On the 12th fishermen in the Brickyard Drift, east of the Columbia River Interstate Bridge, complained for the first time of fouled nets, and sent in samples. The samples consisted almost entirely of new, growing Sphaerotilus in large masses, similar to the appearance of this organism when growing as a coating on pilings. There was little fiber, trash, or other substrate present. This biological mass differed from that found farther down the river in that it could be easily removed from the nets. The channel at this point follows the Washington shore, and the growth was concentrated there. When the fouled nets were drifted closer to the Oregon shore, where the water was cleaner, most of the material washed away rapidly.

There are at least three kinds of slime or biological masses affecting gill nets:

a. Slime composed mostly of wood fibers, stuck together by decomposed Sphaerotilus and perhaps mucilaginous algae, which is very

difficult to get off nets when wet and nearly impossible to remove when dry as it hardens to a substance resembling putty or plastic wood.

b. Biological masses with a heavy content of plant trash and leaf and grass fragments which adhere to nets when wet, but crumble away when dry.

c. Masses composed almost entirely of Sphaerotilus which are easily removed. This type of growth probably develops on fixed surfaces and breaks loose.

Distribution of Suspended Slimes in the Columbia River

a. Bottom Deposits and Attached Growths: During snag-removing operations preceding the gill net seasons, skin divers look over much of the bottom of the river from Bonneville to the mouth. At other times they also spend time on the river looking for sunken boats, motors, tools, etc. Every one of the skin divers interviewed has stated that he has not observed deposits of slime, fiber, or ooze anywhere on the Columbia below Bonneville. The bottom consists generally of clean sand, varied here and there by rock ledges and piles of rock or gravel spilled from barges.

The only attached slimes found in the Columbia are those growing on pilings up to a few hundred feet below outfalls from various industries. These attached growths are insignificant in amount and are composed almost entirely of masses of Sphaerotilus. This is not the case with most of the suspended slimes.

b. Non-Attached Growths: Essentially all drifting slimes seem to originate in the growth of Sphaerotilus-type, filamentous, slime-secreting bacteria on suspended organic substrates. These attachments are of plant

origin and include wood fibers, sawdust, softwood tree needles, fragments of leaves and grass, and bits of paper. Attachment to other suspended detritus, such as diatoms, sand grains, shed insect and crustacean skins, and the like, occurs infrequently, if at all. The size of the substrate materials ranges from a few microns in the case of small wood fibers to several inches across in the case of dead leaves, but most are less than an inch in length. In relatively quiet water, as in impoundments, each substrate particle becomes surrounded with a ball-like growth of bacteria. In turbulent waters, such as the Columbia River, the flocs more often assume an irregular, extended, thread-like form. Because the flocs are sticky, they tend to adhere together in twisted, twine-like masses up to several inches in length, and it is these stringy flocs which so easily lodge against gillnets and lines. Investigators have found that these flocs begin to form rapidly below outfalls containing suitable nutrient concentrations. Flocs reach maximum size about 0.6 mile below the outfall. At approximately six to twenty miles below the outfall (at flows of two to three miles per hour), disintegration begins. Starting at the center, flocs become progressively darker in color and crumbly in consistency. The end product of the decomposition process is a dark-brown amorphous mass in which filaments can no longer be distinguished.

c. Vertical Distribution of Drifting Slimes: European work on distribution of drifting slimes below sulfite pulp mills has shown that there is much more of it in the bottom waters than near the surface (16). This appears to be generally true in the Columbia

River. Gill net fishermen here are convinced that the slime concentrates in the ship channel. For example, if the channel is close to the north shore, there may be no noticeable slime in the southern half of the river. From the center toward the north shore, nets collect progressively more slime. Every effort is made to keep nets out of the channel where the slime concentration is greatest. These nets drag the bottom and extend upward for about five feet above the bottom. Suction-pump sampling at different depths shows in general the same thing, although no systematic cross-section sampling of the river has been done. There are, however, at least three exceptions to slime concentrations in the channel:

1. Where the channel crosses from one side of the river to the other. In this case, the slime is washed out of the channel, and the entire river may be dirty for some distance below.

2. Below sharp bends in the river. Turbulent conditions in such situations may sweep slime out of the channel.

3. Strong tidal action in the lower river.

West of Puget Island the slime is found across the entire river. Strong tidal currents are responsible for this. There is much top-to-bottom turbulence during tidal changes as well. When the tide is running in or out, large "boils" are constantly breaking the surface, and masses of fiber and debris rise in the boils. In the slack water between tides, much of this material sinks out of sight. In the Beaver Army Terminal area it is calculated that tides will exert the greatest effect on slime when the river discharge is below 220,000 cfs*. The combination of low river flow and flooding portions of maximum tides will result in virtual

*See explanation of Evaluation Procedures in Appendix C.

stoppage and reversal of the river current. During these periods the slime will settle to the lower-velocity layers and, on the ebb tide, will move downstream but at a slower rate than if it had remained in the higher-velocity layers. The net effect would be a greater concentration of slime during the critical tidal and low-flow periods. Most complaints from fishermen during 1964 concerning slime came from the lower river.

FISHERMEN'S REPORTS

Late in 1960, a reporting program was initiated in cooperation with the commercial fishermen to gather more specific information regarding the frequency of occurrence and severity of the slime problem. Forms were provided for fishermen who work the various drifts, on which they were asked to report river conditions and the relative amounts of slime encountered during their fishing operations. Some were more diligent than others and provided a continuous record of conditions during the fishing season, while others reported only when conditions were bad. Such data reflect the river conditions only during the six yearly commercial fishing seasons (about 116 days a year). Except for the first season, there are weekly closures of up to four days.

The fishing schedule is such that it is possible for the intermittent waste discharge from Camas to pass through the upper river drifts while the season is closed. Reportedly, some of the fishermen are selective and either do not fish or avoid sections of their drifts where slime is known to exist. Because of these factors, it is impossible to note the effects each of the intermittent discharges has upon all of the drifts.

The intermittent waste discharge from Camas causes a change in water quality and in river conditions that can be traced with water quality tests (12), and these tests have confirmed calculated river flow data. Each fisherman's report was reviewed initially to determine if the reporting period coincided with the passage of an intermittent discharge through the drift. The following pertinent observations can be drawn from the tabulation of the fishermen's reports with river conditions:

1. Reports were received of either live or dead, or both live and dead slime at drifts on the Lower Columbia River for a discharge range of 81,660 cfs to 437,130 cfs and a temperature range of 5.6° C. to 21.1° C.

2. May 2-11 was reported as the worst period of slime occurrence during the 1964 season for the Mayger, Eagle Cliff, and Wauna Drifts when the river discharge ranged from 184,200 cfs to 235,390 cfs, and the temperature ranged from 10° C. to 12° C. Some fishermen reported the slime problem during this period to be the most severe in many years. Some of them had to cease fishing entirely because their nets would sink, due to the large accumulation of slime. The picture on the following page, taken on May 6, 1964, shows the severity of the problem in this area.

3. The amounts of slime reported fluctuated during late July and August 1963 when the river flow was gradually decreasing. This variation is believed to be indicative of the effects of intermittent waste discharge.

4. During the February 25-28, 1964 period, troublesome slime was reported at the Mayger and Eagle Cliff Drifts, but the situation was

Photo by Horn Photo
Clatskanie, Oregon, May 6, 1964

MASSIVE SLIME ACCUMULATION
ON COMMERCIAL FISHERMAN'S NET

not as serious as that encountered on May 2-11. The flow range at these drifts during this period was 169,460 cfs to 201,490 cfs with 5.6° C. temperature.

Also, reports during the September 14-25 period indicated considerable slime occurring at the same drifts. The flow range during this period was 84,873 cfs to 132,203 cfs. River temperature ranged from 16.7° C. to 17.8° C.

5. The tabulation for the 1964 season shows that during the estimated periods when the Crown Zellerbach intermittent discharge was passing through the drifts, frequently the increased severity of slime was reported at the same time. The combination of low flow and tidal effect results in variable slime intensities in the lower river.

6. Generally, on the basis of the fishermen's reports, most of the slime was present about two or three feet from the bottom. This substantiates the conclusion of the German investigators that in large, deep rivers, about two-thirds of the living "sewer fungus" (slime) occurs in the bottom water layers.

Details pertaining to the Columbia River discharge record for Bonneville, temperature data, and the commercial fishing seasons are included in Appendices D, E, and F, respectively.

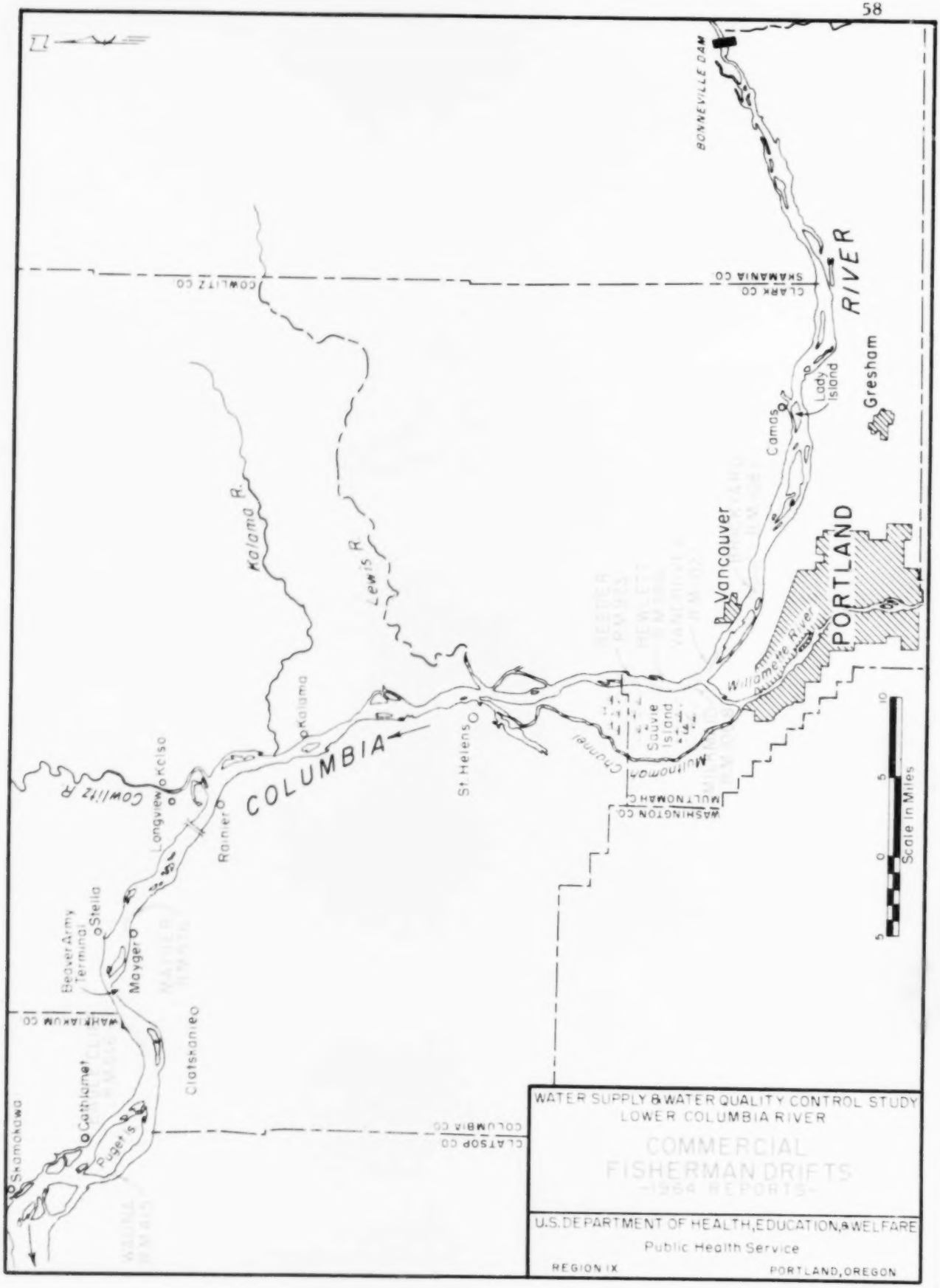
BONNEVILLE DAM
COLUMBIA RIVER
SKAMANIA CO
CLARK CO
COWLITZ CO
Lady Island
Camas
Gresham
Vancouver
PORTLAND
Willamette River
Sauvie Island
Multnomah Channel
WASHINGTON CO
MULTNOMAH CO
Kalama R.
Lewis R.
Kalama
Longview
Cowlitz R.
Rainier
St Helens
COLUMBIA
Beaver Army Terminal
Stella
Mayger
WAHKIAKUM CO
Clatskanie
Skamokawa
Cathlamet
Puget I.
CLATSOP CO
COLUMBIA CO
Scale in Miles
10
5
0
5
WATER SUPPLY & WATER QUALITY CONTROL STUDY
LOWER COLUMBIA RIVER
COMMERCIAL
FISHERMAN DRIFTS
-1964 REPORTS-
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX
PORTLAND, OREGON

FIGURE III

REDUCTION OF FIBER AND BOD LOADINGS

Two constituents present in pulp and paper manufacturing wastes discharged to the Columbia River contribute to the slime problem in the stream. Evidence indicates that slimes develop on suspended fiber discharged by the mills. There is also evidence pointing to the proliferation of slime growths due to nutrient contributions contained in mill wastes. Principally this concerns the carbohydrate fraction available in readily usable form. Similar slime growths may be encountered on smaller streams below points of sewage, canning, and milk-waste discharge where sugars may promote slime development.

The suspended fiber contained in pulp and paper mill discharges may be efficiently reduced in quantity by the provision of adequately designed sedimentation facilities. While several such treatment facilities are in operation in the Pacific Northwest, primary treatment for pulp and paper wastes is more commonly employed in other sections of the country. Installation of mechanically cleaned sedimentation facilities for treatment of pulp and paper wastes discharged to the Columbia River would remove the majority of objectionable wood fiber presently reaching the river in mill effluents.

The nutrient load, consisting of carbohydrate-type materials, is contained in a variety of wastes from the pulp and paper industry. The principal source consists of spent pulping liquors discharged to the stream. Chemical recovery from spent pulping liquors, employed by all but two mills on the river, also destroys the great majority of the nutrient load originating from the chemical pulping of wood. Both the

Camas and Vancouver sulfite mills employ calcium base liquor and discharge all pulping wastes to the stream. In addition, spent sulfite liquor is barged to the Columbia River from a mill located at Oregon City, Oregon. A significant reduction in the nutrient load, as measured by BOD can be obtained by destruction or utilization of sulfite pulping solids produced at Camas and Vancouver, and elimination of spent sulfite liquor barged to the Columbia River.

The processes available to reduce BOD loadings from spent sulfite liquor consist of (1) recovery, (2) destruction, and (3) utilization. While recovery is practiced for retention of more valuable pulping chemicals, calcium is of little value to the industry. Evaporation of calcium base liquor, similar to Kraft recovery methods of burning for heat recovery, is a low-value utilization. This largely destroys the BOD load contained in pulping liquors. Utilization of calcium base liquor through yeast or alcohol production processes yields a salable commercial by-product. Evaporation and production of whole dried solids, or desugared solids from the yeast and alcohol process, produce commercial products of value. Fractional precipitation with lime is employed to yield recovery products of value for further processing. Each of these methods is presently employed by some calcium base sulfite mills in the United States, with resulting reduction in the BOD load discharged to the stream.

1964 SAMPLING EQUIPMENT AND PROCEDURES

Equipment and procedures used during the 1964 sampling program are as follows:

EQUIPMENT

The possibility that slime would grow on floating detritus rather than on the streambed dictated that sampling methods used in prior years be changed. The new sampling equipment was designed to be mobile and sufficiently flexible to collect large volumes of water samples at various depths and locations. A 25-gallon per minute (gpm), gasoline-driven pump was equipped with a 50-foot long, one-inch suction hose with the intake rigged to orient the inlet upstream. The pump was operated to deliver at least 125 gallons of water for filtration through a sampling net. Initially, a No. 12 bolting cloth (125 meshes/inch) net was used for filtering until a No. 20 bolting cloth (173 meshes/inch) net was found to be satisfactory. This equipment was mounted on an 18-foot boat powered with two outboard motors.

SAMPLING PROCEDURE

At a sampling station the intake device and hose were lowered to a selected depth by means of a steel cable mounted on a meter wheel. The pump was operated for one minute before initiating the sample collection with the net. The net was partly submerged in the river so that the energy from the discharge hose would be dissipated in the water rather than against the net. The elapsed sampling time (five minutes) was determined by either a stopwatch or a watch with a sweep second hand. The material collected on the net was washed from the outside to the bottom, and the contents were

washed into a 16-ounce sample bottle. Ten milliliters of five per cent formalin solution were added as a preservative. The temperature of the water from the discharge hose was recorded during sample collection. In most instances, a sample of the water was collected in a 300 ml glass-stoppered bottle for Pearl Benson Index (PBI) determination. Stations were sampled from the boat by one of three methods: floating downstream with the current, anchoring to a fixed structure in the river, or holding the boat to a selected point with the motors.

SAMPLING LOCATIONS

Initially, the following stations were selected for cross-section and multiple-depth sampling:

River Mile
122.6, near Washougal
106.5, Interstate Bridge
99.3, Hewlett Point
83.8, Columbia City
62.7, below Longview

Sampling was also done in the Willamette River and Multnomah Channel below Portland Harbor. The sampling program was extended to include the Mayger area when an extreme slime problem developed.

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1964 SAMPLE ANALYSIS

STATION	DATE & BONNEVILLE FLOW (cfs)	DEPTH (FEET)	TIME	TEMP. °C.	PBI (mg/l)	BIOLOGICAL ANALYSIS OF SAMPLE
122.6 A[1] (Washougal)	4/27/64	3	1504	10.3		[4]
		14	1520	10.1		
122.6 B[2] (Washougal)	142,900	3	1535	10.0		[4]
		9	1550	10.1		
122.6 C[3] (Washougal)		3	1605	10.1		[4]
		11	1615	10.2		
106.5 A (Interstate Bridge)	4/28/64	3	0812	10.0		[4]
		20	0821	10.0		
99.38 B (Hewlett Point)	141,100	3	1028	10.1		[4]
		29	1040	10.1		
83.8 A (Columbia City)		3	1230	10.9		Wood fiber - sample lost in laboratory
		18	1237	11.0		Wood fiber - sample lost in laboratory
W-0.2 (Willamette Mouth)	5/4/64	6	1432	11.2		Sample consisted almost entirely of algae (98%). Mostly planktonic diatoms, few filaments of filamentous forms. Few cast exoskeletons of microcrustacea, very few pieces of leaf & bark trash. No sand grains.
	181,200					
99.38 A (Hewlett Point)		30	1455	11.1		Most of sample consisted of sand grains. Of organic fraction, plant trash, bark fragments & small bits of groundwood comprise about 85%. Very few wood fibers. Remainder of river plankton, mostly diatoms.
99.23 C (Hewlett Point)		11	1512	11.5		95% algal plankton, mostly diatoms. A few filamentous algae. A few wood fibers (1-2%). Some plant & bark fragments, a few sand grains.
Multnomah Channel M-2 (½ mi. below Sauvies Island Bridge)		30	1121	10.5		70-80% wood fiber & groundwood. No Sphaerotilus. 15% plant trash & bark. 5-10% river plankton & filamentous algae. Considerable number of sand grains.
W-27 (Willamette R. & Multnomah Ch. Junction)		15	1211	10.6		Mostly sand grains. 90% plant trash & bark fragments. 5% river plankton(diatoms), 5% live & dead microcrustacea(Clodocera & Copepoda). Very sparse sample, almost pure water.

STATION	DATE & BONNEVILLE FLOW (cfs)	DEPTH (FEET)	TIME	TEMP. °C.	PBI (mg/l)	BIOLOGICAL ANALYSIS OF SAMPLE
106.5 C (Interstate Bridge)	5/15/64	9	1335		27	
		17	1326		41	
	265,500	28	1316	12.5	24	
55.9 A_3 (Stella)		19	2000	12.3	41	40% wood fiber, 40% bark & plant debris. 20% Sphaerotilus-type organisms & diatom plankton (Fragilaria, Synedra, Cyclotella, Asterionella).
		19	2125		41	Same as above
		19	2230		45	Same as above
55.9 A_1 (Stella)	5/16/64 275,300	24.5	0708		63	Sample similar in appearance to above, except the growing Sphaerotilus is more abundant & the size of debris particles is larger. Considerable number of Copepoda (larva & adult).
55.9 A_2 (Stella)		20	0804		67	30% wood fiber, 30% bark & plant debris. 20% Sphaerotilus & other slime-forming bacteria. 15% diatoms in masses (Synedra, Fragilaria, Asterionella). 5% crustacean & insect exoskeletons, water mold mycelia. Fibers & debris stuck together by both bacterial slimes & diatoms.
		10	0815		70	30% wood fiber, 55% plant debris & bark. Fresh Sphaerotilus growing on fibers & debris. Many coarse sand grains. 15% plankton (diatoms & large sheets of Tetraspora).
55.9 A_4 (Stella)		15	1011		66	40% wood fiber, 55% plant debris & bark. Some fresh Sphaerotilus but less than preceding samples. Few sand grains. Some plant & animal plankton, but less than preceding samples.

STATION	DATE & BONNEVILLE FLOW (cfs)	DEPTH (FEET)	TIME	TEMP. °C.	PBI (mg/l)	BIOLOGICAL ANALYSIS OF SAMPLE
58.2 B (Mayger)	5/16/64 275,300	(Sample Taken From Gillnet)	1100			90% of the material scraped from the gillnet was of microscopic-size leaves, grass, small twigs, bits of paper. Of the microscopic fraction 80% was plant debris, 10% wood fiber & 10% Sphaerotilus & similar slime organisms. Very little plankton present & not much sand. When the gillnet was allowed to dry, most of the attached material crumbled & fell off on shaking. Nets covered with wood-fiber type slime are almost impossible to clean when dry, so this is not the kind encountered in the lower river.
55.9 C (Stella)		46	1205	12.5	63	85% fairly clean wood fibers. Small amount Sphaerotilus growing on some of them. Only a few strands of filamentous algae. Remainder of sample bark & plant debris.
55.9 A_7 (Stella)		15	1222		62	45% wood fiber, 45% trash & bark. Few filamentous algae, small amount plant & animal plankton, few small tufts of Sphaerotilus growing on trash & fibers.
55.9 A_6 (Stella)		15	1235		66	50% wood fiber, 45% trash, small amount plankton. Much microscopic trash (bark, leaf fragments, grass, etc.) in sample.
55.9 A_5 (Stella)		10	1430		60	45% wood fiber, 50% trash. Few plankton, small amount growing Sphaerotilus on trash and fiber.
55.9 A_7 (Stella)		10	1440		60	60% wood fiber, 35% plant debris & trash. Few plant & animal plankters. Some insect & crustacean skins.
83.8 A (Columbia City)	5/19/64 292,200	30	1030	13.0	58	80% wood fibers. No Sphaerotilus. Few water mold mycelia. 10-15% plant trash & bark. Fairly numerous plankton - Diatoms Synedra, Asterionella, Melosira; green algae Pediastrum, Closterium; Rotifers Filinia, Keratella; Copepods, Cladocerans.

STATION	DATE & BONNEVILLE FLOW (cfs)	DEPTH (FEET)	TIME	TEMP. °C.	PBI (mg/l)	BIOLOGICAL ANALYSIS OF SAMPLE
83.8 B (Columbia City)	5/19/64 292,200	21	1100		78	90% clean wood fibers. No slime, occasional strands of streptococci attached to wood. 5% of bark fragments, plant & green leaf fragments. Some large sand grains. Varied plankton present - Diatoms Fragilaria, Synedra, Melosira, Asterionella; Desmid Closterium; Rotifers Anuraea, Trichotria, Kellicottia; Copepods; Cladocera.
M-6 (Multnomah Channel @ St. Helens)		10	1215	13.3	149	95% clean wood fibers. Almost no slime or bacterial growth. A few streptococcus chains. A few Phycomycetes water mold mycelia. A few small bark fragments. Some sand grains, not adhering to the wood fibers.
M-B (200 yds. downstream of previous sample)		35	1228		95	80% wood fibers. Mostly clean, but tufts of Sphaerotilus growing on some fibers. Some water mold mycelia. Some plankton present as at upstream sampling stations, but much reduced in quantity. Numerous filamentous algal strands, probably from log rafts.
M-7 (Halfway between above 2 stations)		5	1250		125	Essentially as above. A few Copepods present.
		12.5	1256		99	- Same -
M-5 (Water intake & St. Helens Mill)		13	1325		98	80% clean wood fibers; 10% bark particles & plant fragments. Abundant plankton-Diatoms Fragilaria, Melosira, Synedra, Asterionella; Desmid Closterium; Rotifers Collotheca, Anuraea, Filinia, & others; many Copepods & Cladocera.
M-3 (Scappoose Bay)		12	1343		119	85% wood fibers. Appear to be much older & much more beaten up than those from samples close to mills. No Sphaerotilus. Few Diatoms & Desmids. Rotifers, Cladocerans & Copepods fairly numerous. Some filamentous algae (Ulothrix & Spirogyra).

STATION	DATE & BONNEVILLE FLOW (cfs)	DEPTH (FEET)	TIME	TEMP. °C.	PBI (mg/l)	BIOLOGICAL ANALYSIS OF SAMPLE
W-3.7 (Willamette River near Terminal #4)	5/19/64 292,200	45	1528		105	Small amount clean fiber. No Sphaerotilus or other slime organisms. Fair amount plankton, mostly zooplankton - Cladocerans, Copepods, Nematodes, Rotifers. Numerous strands of filamentous algae. (Ulothrix, Spirogyra, Tribonema), few Chironomid midge larvae.
M-1 (Multnomah Channel above Sauvies Is. Bridge.)		20	1545		94	Few clean fibers (60% wood fiber, 40% plant debris). Many large sand grains. Some zooplankton, mostly Cladocera, Copepods. Very few plant plankters.
105.8 C (Between RR Bridge & Boise-Cascade)		20	1617		7	95% clean wood fibers. A very few small knots of living Sphaerotilus growing on some fibers. Very little animal or plant plankton, mostly Rotifers & a few strands of filamentous algae.

1/ Oregon side
2/ Center
3/ Washington side
4/ A very small amount of sand and leaves was collected in the sample. No fibers or slimes were observed. The sample was not saved for laboratory analysis.

EXPLANATION OF RIVER EVALUATION PROCEDURES

GENERAL INFORMATION

In order to evaluate the fishermen's complaints obtained on the Lower Columbia River to date, all data, including the fisherman reports, river discharge, and temperature were tabulated for the period 1960 to the present. The fisherman reports were first analyzed on the basis of date, drift, general slime conditions, and river discharge. The most consistent reporters were those fishing at the Eagle Cliff (R.M. 51.6), Mayger (R.M. 57.6), and Wauna (R.M. 41.5) Drifts; however, a number of reports were received from upriver fishermen in the Vancouver-St. Helens area.

On the basis of reports of severe slime conditions received during the 1964 fishing operations, it was decided to examine in more detail all the fisherman reports. In so doing, an effort was made to correlate the fishermen's complaints with Crown Zellerbach Corporation's lagoon waste discharge periods, river temperature, river discharge, and tidal effects. (The latter item was examined particularly in the lower river areas where it has the greatest effect on fishing operations.)

CROWN ZELLERBACH WASTE DISCHARGE PERIODS

In order to relate the Crown Zellerbach "slug" periods with complaints from downstream fishing drifts, it was necessary to have some idea of the time of water travel from Lady Island outfall to the drifts for various river discharges. Due to the complex tidal problems encountered in the Lower Columbia, an accurate determination of time of travel is very difficult; however, a good estimate can be made. For the purposes of this

report, the following estimate was made: A graph was constructed of time of passage versus river mileage from Lady Island outfall for various river discharges, using the flow equation $Q = VA$; where Q = discharge, V = average river velocity, and A = river cross-sectional area. This graph represents the standard flow curves and excludes all tidal effects, but it does give a good estimate of travel time, particularly in the upper reaches.

Travel times taken from this graph were compared with the actual times observed in a Crown Zellerbach Corporation publication (12) and were found to compare favorably at similar river discharges. Next, daily flows of all the major tributaries of the Willamette and Columbia Rivers were averaged over a three-year period, 1961-1963, on a monthly basis in order to estimate the inflows to the Columbia at various locations in the study area. These inflows were then added to the daily recorded Bonneville discharges at their respective influences to account for all ungaged Columbia discharge. To give an accurate estimate of discharge travel times, the total Columbia River flows were averaged over four-day periods beginning with the first day of Crown Zellerbach lagoon waste discharges. Using this procedure, time of travel was generally estimated in three stretches of the river below Lady Island outfall: Lady Island outfall to Willamette River mouth, Willamette River mouth to St. Helens, and St. Helens to the lower drifts. The estimated travel time required for Crown Zellerbach lagoon "slugs" to reach and traverse the fishermen's drifts was determined in this manner.

RIVER TEMPERATURE

Since the fishermen do not report river temperatures at their drifts, the exact daily temperatures are not available, but the daily Columbia River temperatures at Bonneville Dam are tabulated. The recorded temperatures at Bonneville Dam were compared with those observed in the lower river at the Clatskanie, Oregon, WPSS station, and the difference was found to be small. For the purposes of this report, Bonneville temperature recordings have been used.

RIVER DISCHARGE

Recorded river discharges at Bonneville Dam have been used throughout this report. As was previously stated, the estimated ungaged readings have been added when necessary to determine more accurately flows at the drifts.

TIDAL EFFECTS

Tidal effects at the lower drifts, in particular at Beaver Army Terminal, were estimated. Generally, determinations at Beaver Army Terminal were indicative of the tidal fluctuations at the Mayger, Eagle Cliff, and Wauna Drifts. The estimation of tidal effects is based on information obtained from the U. S. Army Corps of Engineers report entitled "Review Report on Columbia and Lower Willamette Rivers Below Vancouver, Washington, and Portland, Oregon," with particular emphasis on their "1959 Current-Measurement Program Interim Report." Tidal height, tidal velocity, and river discharge data were obtained for a selected nine-day period during each of the months of May, June, and September 1959. With this information,

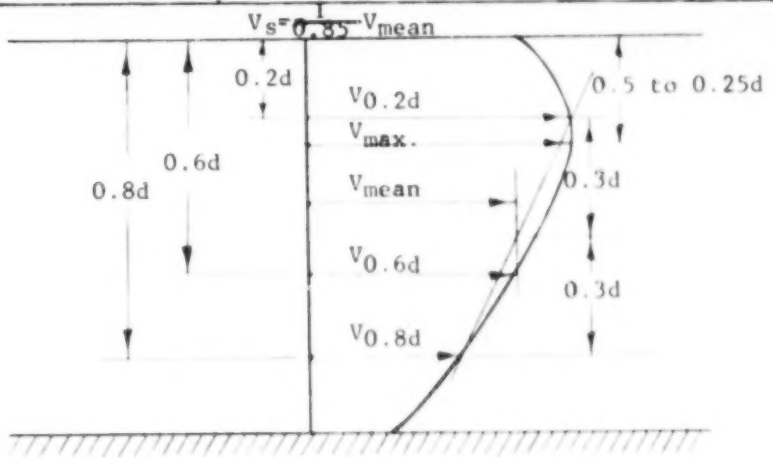
an idea of the over-all tidal fluctuation occurring at maximum, minimum, and average river discharges was obtained. Also, the 1959 tide information would be similar to all yearly tide effects. A graph of tidal velocity versus tide amplitude was constructed for the Beaver Army Terminal area. Next the daily mean and diurnal tide ranges and their respective tidal velocities were computed for 1963 and 1964. Since the mean tidal range is the average of all daily tidal ranges and the diurnal range is the average range of the daily maximum tides, an idea of the worst tidal conditions that could occur and an idea of the average daily tidal conditions that could occur are known.

Then, the velocity due to river discharge at the Beaver Station was compared with these tidal velocities. When the tidal velocity becomes greater than the average river discharge velocity, there are virtually complete stoppage and reversal of the river flow. Using this procedure, it was estimated that generally all river flows at Beaver Station below 220,000 cfs would be stopped or reversed by tidal velocities on the incoming or high tides. On the ebb tide there would be a rush of water downstream. Hence, at all river flows in the Beaver area below 220,000 cfs there is a tidal stoppage or reversal of river flow during the high tide period. This period of ceasing flow could vary from one to six hours.

In order to more clearly understand the slime problem during these periods of tidal stoppage and reversal of river flow, the following plot

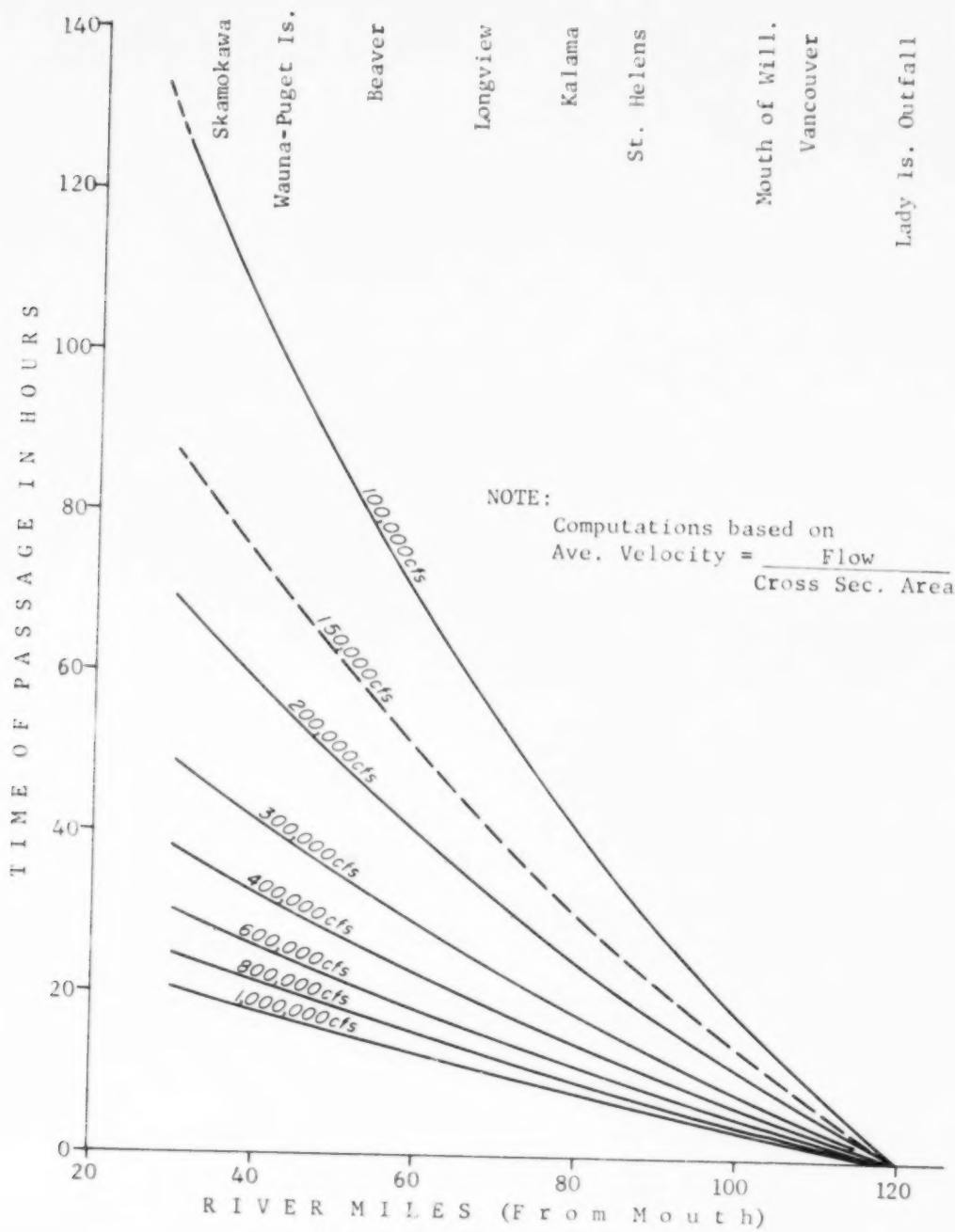
of the standard velocity distribution in a river such as the Columbia is introduced:

Standard Velocity Distribution in a Vertical in Open Flow (17)



It is noted the average velocity occurs at approximately 0.6d below the water surface. All river velocities at layers below this depth become increasingly smaller, and at the very bottom of the river the velocity is approaching zero. During periods of river discharge in which the high tide ceases and reverses the flow, it is felt that the slimes settle to the lower velocity layers and on the ebb tide these slimes are flushed downstream, but at a slower rate than if they had remained in the upper velocity layers. Furthermore, as the average river velocities decrease, the depths at which these velocities occur more nearly approach the bottom layers of low velocity. Consequently, larger amounts of slime will be transmitted to the lower velocity layers. Also, since the duration of the high-tide period at the lower flows is greater than at high flows, the slimes will have more time to settle to these lower velocity

layers. Therefore, it is concluded that the tidal fluctuation will have its greatest effect on the slime problem during periods of low river flow. As was mentioned earlier, the critical flow would be approximately 220,000 cfs at the lower drifts. The net effect during low-flow periods would be a greater accumulation of slime. This tide estimate was used throughout the evaluation of fisherman reports.

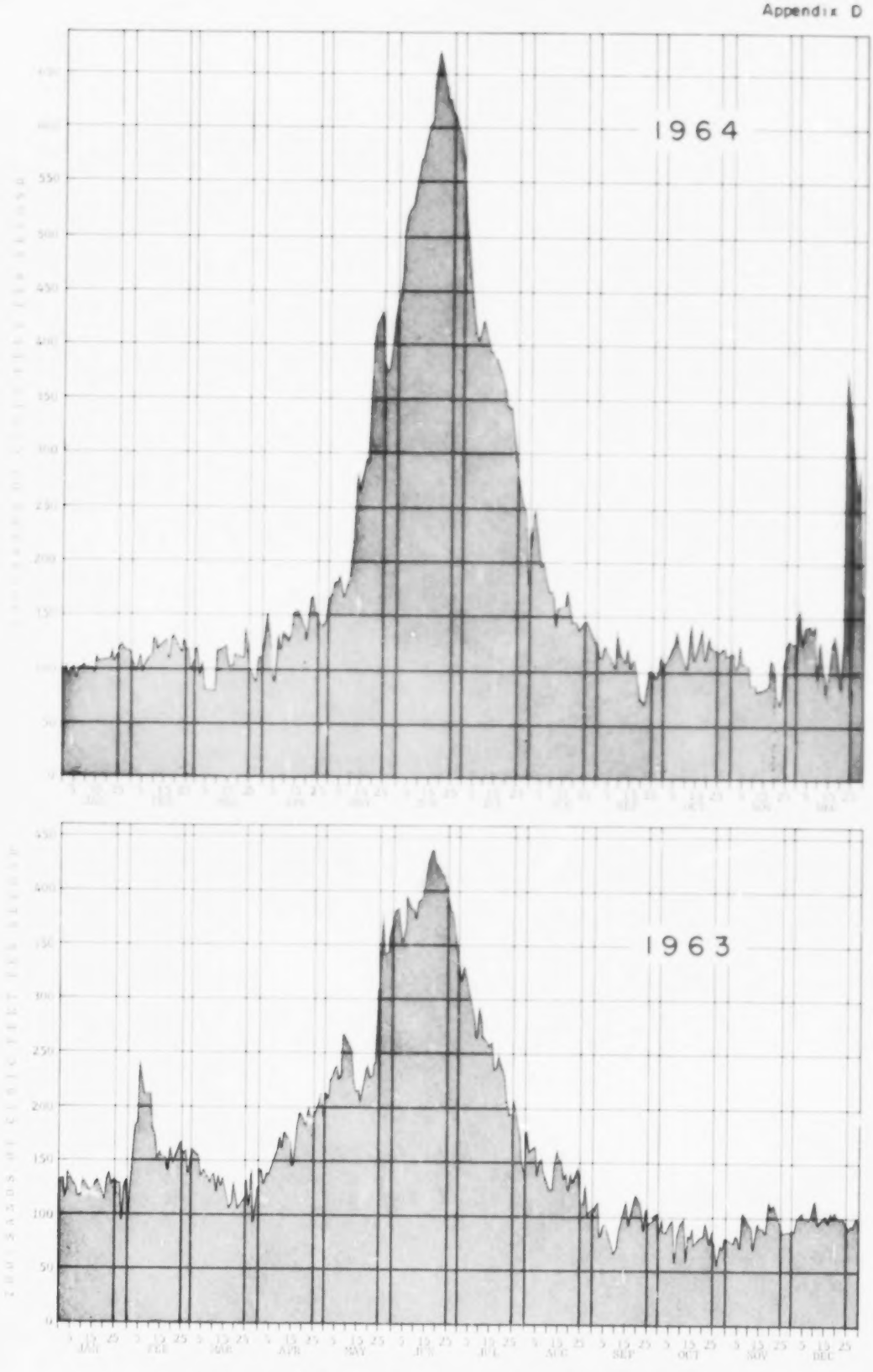


COLUMBIA RIVER

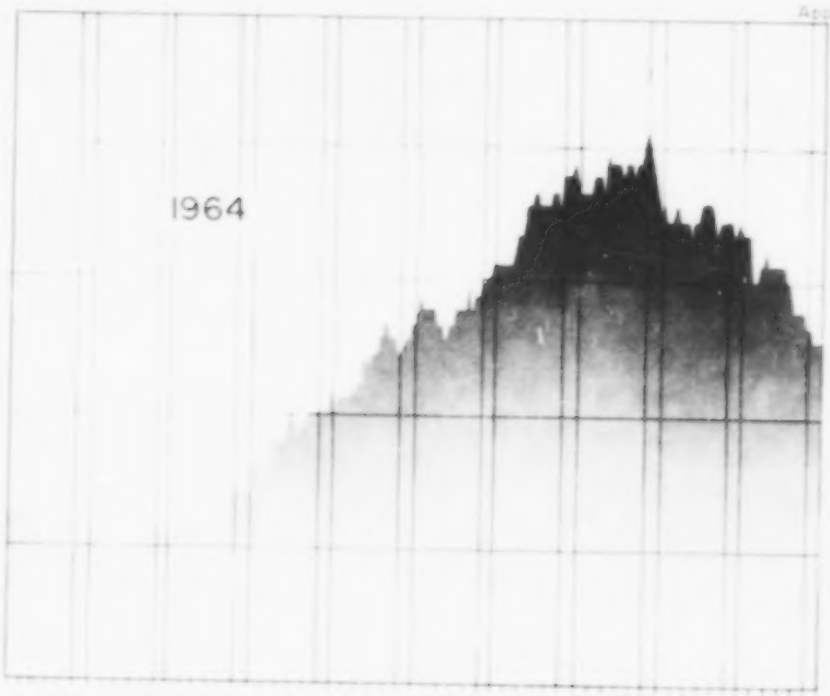
ESTIMATED TIME OF PASSAGE OF NET* FLOW FOR VARIOUS RIVER DISCHARGES

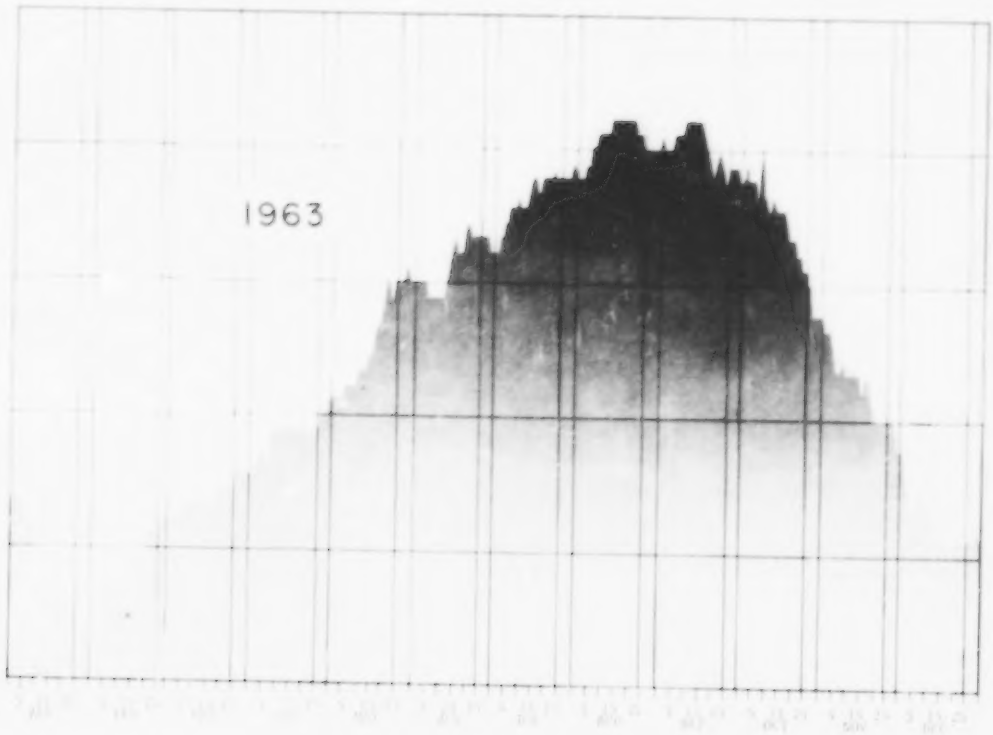
Downstream From Lady Is. Outfall

*Excludes Tidal Effects



COLUMBIA RIVER DISCHARGE
AT BONNEVILLE DAM 1963 – 1964





COLUMBIA RIVER TEMPERATURE
AT BONNEVILLE 1963-1964

COLUMBIA RIVER COMMERCIAL FISHING SEASONS

1963	1964
February 15 to March 1	February 15 to March 1
April 30 to Noon May 4	7 PM May 3 to 1 PM May 9
6 PM May 5 to Noon May 11	7 PM May 10 to 1 PM May 16
6 PM May 12 to Noon May 18	7 PM May 17 to 1 PM May 23
6 PM May 19 to Noon May 25	7 PM May 24 to May 27
6 PM May 26 to May 27	June 6 to June 9
6 PM June 16 to Noon June 22	June 22 to June 24
6 PM June 23 to Noon June 29	July 29 to 7 PM July 31
6 PM June 30 to Noon July 6	7 PM August 2 to 7 PM July 31
6 PM July 7 to Noon July 13	7 PM August 16 to 7 PM August 21
6 PM July 14 to July 15	7 PM August 23 to August 25
July 29 to 6 PM August 2	September 14 to September 18
6 PM August 4 to 6 PM August 9	September 21 to September 25
6 PM August 11 to 6 PM August 16	September 28 to October 1
6 PM August 18 to 6 PM August 23	October 5 to October 8
6 PM September 16 to 6 PM September 19	October 12 to October 15
6 PM September 23 to 6 PM September 26	October 26 to October 31
6 PM September 30 to 6 PM October 3	
6 PM October 7 to 6 PM October 10	
6 PM October 28 to 6 PM October 31	

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